Journal of CHEMICAL EDUCATION

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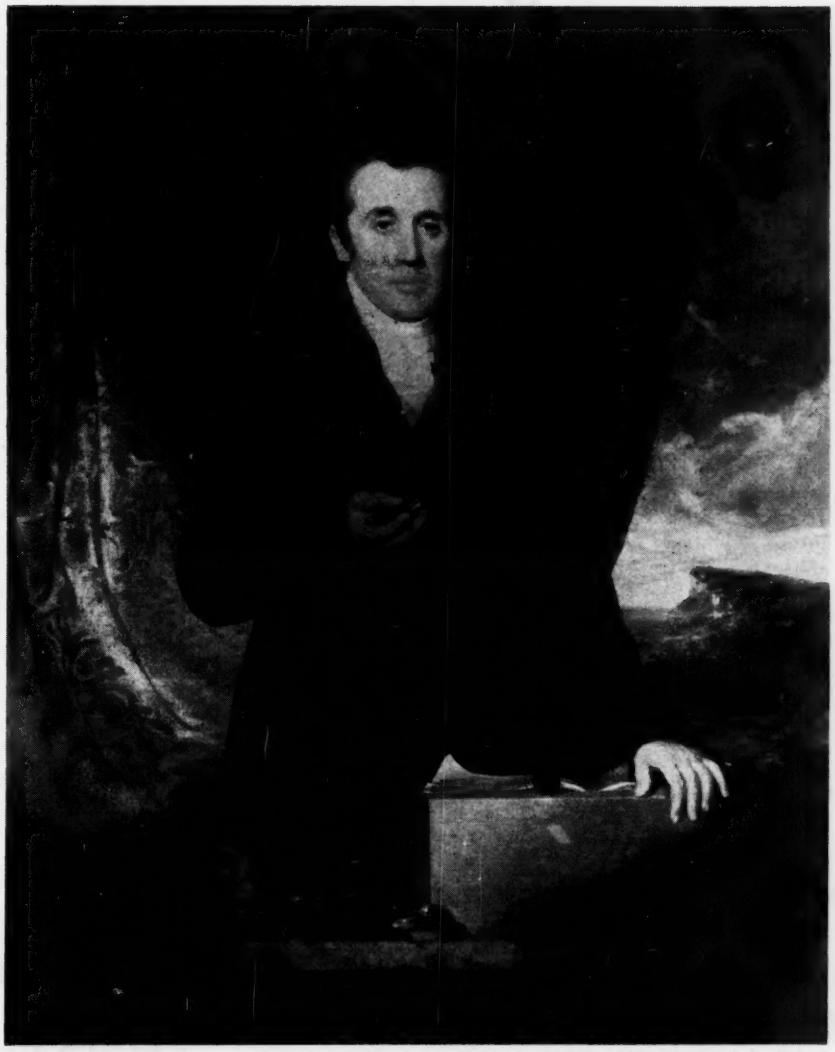

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BENJAMIN SILLIMAN

after whom Silliman College of Yale University was named (see page 342)

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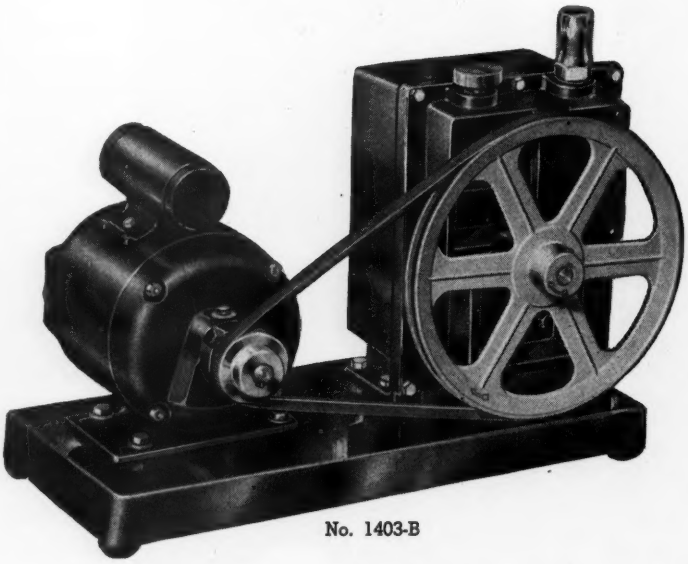

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Editor's Outlook

OUR readers will remember that they received, some months ago, an editorial questionnaire in which they were asked to express themselves on certain matters of editorial policy and to offer suggestions for the improvement of the JOURNAL.

To us, the results of this were not only interesting but valuable. We learned a great many things about our readers, their likes and dislikes. Some of our policies were confirmed and some discredited—as was to be expected. A large number of useful suggestions were made, some of which we propose to follow. Many more we would follow if we were able to do so. A few readers took the opportunity to tell how little they thought of us, and that was good for our vanity.

Long before this we had known that it was impossible to please everyone all the time. It was not surprising to note that every point that was vigorously criticized by someone was enthusiastically supported by someone else. One says: "Let's have no more drivel such as that in the article by Smith and Blank." Another says: "The best thing I have seen in a long time was the Smith and Blank article. How about some more like that?"

Nearly 1800 replies were received, more than a third being from college teachers, and about one-quarter each from high-school teachers and from those who described themselves as industrial chemists. About 10 per cent thought the general level of the JOURNAL too elementary, 13 per cent thought it too advanced, and 27 per cent indicated that it was about right.

In more than a general way, the results of this questionnaire corroborate those of previous ones, carried out on a less extensive scale. The most consistent desire of our readers is for "review articles," either of practical industrial or of theoretical advances in the general field of chemistry. Gadgets, new apparatus, and demonstration experiments are the subjects next most popular. Historical articles, original research, and teaching and examination techniques are of rather less interest, while popularizations and the High-School Section trail along at the end.

Among the regular features or "departments," book reviews and the "What's Been Going On" column are the most popular, followed rather closely by editorials and the "Editor's Basket" column. The reviews of trade literature and of recent chemical patents have relatively little appeal.

However, the whole analysis of reader interest is made difficult by the heterogeneous character of the reader list itself. In only two cases (High-School Section and Chemical Patents) did more than a third of the readers express complete lack of interest, and it is perhaps safe to assume that if an article or feature has interest for more than two-thirds of the readers, its publication is justified.

We learn that our readers, on the whole, want more illustrations, more articles of general interest and about laboratory apparatus, more emphasis upon content (rather than teaching) and upon theoretical and advanced topics. In fact they want more of almost everything. We wish we could supply it!

If we could put into practice the many gratuitous suggestions and comments that were made (allowing, of course, for those which directly contradict each other) we would have a journal which no teacher or chemist could afford to do without. Obviously, this will be impossible because of limitations of time, space, money, and help. But as far as practicable, we shall follow much of this excellent advice, and we shall try to find authors for as many of the suggested articles as we can.

As we have repeatedly pointed out, "chemical education" means different things to different people. Some of our readers expect the JOURNAL to be exclusively a teachers' magazine. Many of those on our circulation list, however, are not teachers, and for them chemical education has a broader meaning. One of them, after suggesting that the content of the JOURNAL should be partly intended for those who had gone through college, goes on to say:

> The word "education" is the key. Whether a chemist knows it or not, his education should never cease, and more chemists should be aware of this.

Another comment along the same line read:

> For chemists in industry who have not found it economically possible to continue in school your journal furnishes one of the few means of keeping in touch with the inspirational atmosphere of the college campus. As a result, I find that as I read the various articles of interest in your journal, I get a fresh drive to go on into new fields; and, too, it keeps one's outlook a little less microscopic.

Another reader says:

> I think every chemist should read at least one article a month on a subject having no apparent connection with his work.

For such as these, chemical education is more than the formal atmosphere of the classroom, and for them the JOURNAL must be something more than a pedagogical crutch.

One point was misunderstood so many times that it had better be cleared up. Several readers commented on the amount of space given to the New England Association of Chemistry Teachers. Evidently there are still many who do not understand the relation between the JOURNAL and the N.E.A.C.T. The total membership of this association has a subscription to the JOURNAL at a group rate, in return for which the JOURNAL allocates two pages monthly to the *Report* of the Association (which was previously published independently). The Association may use this space for any purpose it sees fit, subject to approval by the Editor. Two pages were *added* to the regular editorial

(*Continued on page 344*)

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ANCIENT GREEK PIGMENTS[1]

EARLE R. CALEY[2]

Wallace Laboratories, Inc., New Brunswick, New Jersey

IN THE academic year 1935–36 S. W. Midgley, Jr., a student of chemistry at Princeton, undertook as a senior thesis project under the author's direction the identification of a number of specimens of ancient Greek pigments scraped mostly from objects of terracotta, or fragments of such objects, found in the course of excavations at or near the ancient market place, or Agora, at Athens. In the first half of the year 1937 the author examined and identified a number of specimens of pigments from the Agora while serving as chemist of the excavation staff. Unlike those examined by Mr. Midgley, these were not decorative pigments detached from terracottas or other objects but for the most part were substantial specimens or small remains of bulk pigments found in the vessels, or the remains of the vessels, in which these pigments had been stored or in which they had been mixed for application. Subsequent to these two investigations a few other specimens of ancient Greek pigments were examined and identified by the author. The present paper is a much-belated summary of the most interesting and significant results of all this work.

A usual difficulty encountered in the scientific examination of ancient pigments is the small amount of material available for analysis. This necessitates the use of microchemical or semimicrochemical methods, and most of the specimens here described were analyzed by such methods. Since the procedures employed were either conventional or were simple modifications of conventional procedures, no details of these procedures need be given.

In Table 1 are summarized the principal results obtained by Mr. Midgley, and in Table 2 those obtained by the author. It will be noted that quantitative results are given for the ferric oxide content of the red iron oxide pigments listed in Table 1. These results may be taken as indicative of the purity or quality of these pigments. Quantitative estimations actually were made of the principal components of all five such pigments listed in this table, and as an example of a nearly complete quantitative analysis made on a very small quantity of an ancient pigment the results obtained on one of them (Table 3) may be of more than passing interest. In this analysis the silicon dioxide, the aluminum oxide, and some of the water represent chiefly the sand and the kaolin or clay admixed with the iron oxide in the natural ochre. The considerable proportion of calcium oxide revealed by the analysis is possibly an indication of a deliberate admixture of lime or chalk with the ochre when it was applied or of the use of a lime wash as an undercoat for the application of this pigment in the form of a tempera paint. Considerable proportions of calcium oxide were found in some of the other red iron oxide pigments, although sometimes it was absent, as in Number 1 of Table 1. In Number 9 of Table 1 a considerable part of the calcium was present as the sulfate, a compound that is not normally a component of natural red ochre. Moreover, from the uniform light pink color of this pigment it would appear that the calcium sulfate in the form of powdered gypsum was mixed with it before application, though it may have been contained in an undercoating consisting of a

TABLE 1

PIGMENTS FOUND MOSTLY ON TERRACOTTA OBJECTS

Number	*Description*	*Approximate century B.C.*	*Identification*
1	Dark brick-red pigment	VII	Red ochre (about 48 per cent Fe_2O_3)
2	Yellow pigment on same fragment as No. 1	VII	Yellow ochre
3	Dull red pigment	VII	Red ochre (about 15 per cent Fe_2O_3)
4	Bright red pigment on lekythos	IV	Cinnabar, natural mercuric sulfide
5	Green pigment on draped female figure	IV	Malachite, natural basic copper carbonate
6	Light red pigment	III	Red ochre (about 17 per cent Fe_2O_3)
7	Yellow pigment	II	Yellow ochre
8	Red pigment on sherd	III–II	Red ochre (about 13 per cent Fe_2O_3)
9	Pink pigment	III–II	Red ochre diluted with gypsum, natural calcium sulfate (about 3.5 per cent Fe_2O_3)
10	Blue pigment	III–II	Blue frit, artificial calcium copper silicate

[1] Presented before a joint meeting of the Division of the History of Chemistry and the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 11, 1946.

[2] The experimental work described in this paper was done while the author was a member of the Department of Chemistry, Princeton University, and chemist on the staff of the American Excavations in the Athenian Agora.

TABLE 2
SPECIMENS OF BULK PIGMENTS

Number	Description	Approximate century B.C.	Identification
1	Roughly spherical ball of medium blue pigment weighing 13 grams	VI–V	Blue frit, artificial calcium copper silicate
2	Heavy coating of dull red pigment on inside of base of pot	VI–V	Red ochre
3	Dull red pigment adhering to inside of three vase fragments	V	Red ochre
4	Traces of bright red pigment on part of inner side and on adjacent part of rim of small black bowl	V	Cinnabar, natural mercuric sulfide
5	Lumps of smooth white pigment found in grave with remains of vessel	V–IV	White lead, artificial basic lead carbonate
6	Small amount of medium blue pigment in half of small black glaze bowl	IV	Blue frit, artificial calcium copper silicate
7	Specks of red pigment imbedded in design of fragment of black glaze stamped plate	IV–III	Red ochre
8	Small amount of bright red pigment contained in a scallop shell	III	Cinnabar, natural mercuric sulfide
9	Deposit of red pigment on bottom of ribbed kantharos fragment	II	Red ochre
10	White pigment coating inside of bottom of fragment of black glaze bowl	II–I	Chalk, impure calcium carbonate
11	Heavy coating of yellow pigment on inside of two fragments of black glaze bowl or dish	II–I	Yellow ochre diluted with chalk
12	Dark brownish red pigment coating inside of fragment of bottom of a pot	I	Red ochre

plaster wash.' Of the various pigments listed in Tables 1 and 2 only the blue frit and the white lead are clearly of artificial origin. It is possible that some of the specimens of red ochre were pigments manufactured by the roasting of yellow ochre, but no evidence for this could be found in the course of their examination. All the other pigments are simply natural mineral products used directly in their native state or used after having been subjected to some sort of a mechanical refining process. Since cinnabar, for example, is usually found admixed with rocky gangue, it is highly probable that this pigment was obtained by a process of mechanical separation such as that described by Theophrastus of Eresos[3] in his "Treatise on Stones" written near the end of the fourth century B.C. The production of certain of them by mixing together natural products is also very probable as has been previously indicated. Moreover, the existence of such a practice in Greece during the classical period is evident from certain remarks of Theophrastus.[4]

Some of the pigments here identified were undoubtedly imported products. Since there is no evidence for the present or past occurrence of cinnabar in Greece proper, that found in the Agora or vicinity was almost

[3] *De Lapidibus*, 58, 59.
[4] *op. cit.*, 53.

TABLE 3
QUANTITATIVE ANALYSIS OF SPECIMEN NUMBER 8 OF TABLE 1

(Total quantity used for analysis, 0.0469 gram)

Compound	Per cent
Silicon dioxide (SiO_2)	36.5
Aluminum oxide (Al_2O_3)	15.6
Ferric oxide (Fe_2O_3)	13.0
Calcium oxide (CaO)	15.8
Magnesium oxide (MgO)	2.3
Loss on ignition ($CO_2 + H_2O$)	16.4
Total	99.6

certainly imported. The nearest source, as indicated by Theophrastus[5] and shown by modern geological exploration, was western Asia Minor, and certain more distant sources in Transcaucasia, also mentioned by this author, may well have been the source of the pigment. The blue frit was in all probability imported directly or indirectly from Egypt. This beautiful blue pigment was made there as early as the Fourth Dynasty and became common shortly after.[6] Its Egyptian origin is specifically mentioned by Theophrastus,[7] who also notes that it was a manufactured product. Apparently, it was only at a time later than the date of the specimens here identified that this artificial blue pigment came to be manufactured anywhere on the continent of Europe. According to Vitruvius,[8] it was first manufactured at Puteoli by Vestorius. There is no evidence that it was ever made in Greece. The shape of the bulk specimen found at the Agora is of considerable interest as indicating the probable form in which this pigment was sold for use. Moreover, from the description of Vitruvius it seems certain that it was manufactured in just such roughly spherical balls. Possibly some of the ochres were of distant origin, though no concrete evidence for this can be given. Theophrastus[9] mentions the island of Ceos as being the source of the best red ochre and the province of Cappadocia in Asia Minor as a source of both red and yellow ochre. However, ochres of good quality occurred anciently on the mainland of Greece, particularly in Attica, and still can be found there today, so that the specimens here identified may well have been of local origin. It is uncertain whether the white lead was of local or distant origin. Theophrastus[10] describes the process for manufacturing white lead concisely and clearly as though it were well known to him from personal observation, and he apparently wrote this account while residing at Athens. Moreover, abundant lead for its manufacture at Athens could have been readily obtained from the mines at Laurion. On the other hand, ancient writers do not specifically state that white lead was ever manufactured at Athens, though they do mention other places where this pigment was manufactured. Dioscorides,[11] for example, remarks that the best grade was made at Corinth, in Lacedemon, and on the island of

[5] *op. cit.*, 58.
[6] LUCAS, A., "Ancient Egyptian Materials and Industries," Edward Arnold and Company, London, 1934, p. 285.
[7] *op. cit.*, 55.
[8] *De Architectura*, VII, 11, 1.
[9] *op. cit.*, 52.
[10] *op. cit.*, 56.
[11] *De Materia Medica*, V, 103.

Rhodes. Unlike the other pigments discussed here, white lead was apparently never used as a decorative paint pigment but only as a cosmetic.

Certain kinds of pigments known from other investigations to have been used by the ancient Greeks are not among those here identified. No specimen of either orpiment or realgar, the two native sulfides of arsenic, has been found at the Agora although a few specimens of one or the other have been occasionally found at other sites in Greece. Rhousopoulos[12] identified as orpiment a specimen of a yellow pigment found in a Greek grave of the fifth or fourth century, and Foster[13] identified as realgar a quantity of a red pigment contained in a pot excavated at Corinth. No specimen of any black pigment has been found at the Agora although specimens of a particular black pigment have been found elsewhere. Samples of this taken from lekythoi have been identified by Rhousopoulos[14] as pyrolusite, a native oxide of manganese. From their sporadic occurrence the sulfides of arsenic and the black oxide of manganese were apparently not much used.

One of the pigments which Theophrastus[15] lists has not been found in modern excavations and identified. This pigment is verdigris, the preparation of which is so clearly described by him that there can be no doubt that it was made for use as a pigment in his day. That ancient specimens of this artificial basic copper acetate will ever be found, however, is perhaps too much to expect since it is an unstable pigment that is readily transformed by the action of air and water into basic copper carbonate. This chemical instability may be the source of a curious error since it is by no means improbable that some of the specimens of ancient Greek green pigments which have been identified as basic copper carbonate were originally in the form of verdigris.

TABLE 4
CLASSIFICATION OF ANCIENT GREEK PIGMENTS

Predominant color	*Principal colored compound present*	*Natural mineral or artificial preparation actually used*
Red	Fe_2O_3	Hematite and red ochres
	HgS	Cinnabar
	As_2S_2	Realgar
Yellow	$Fe_2O_3 \cdot H_2O$	Yellow ochres
	As_2S_3	Orpiment
Green	$Cu(OH)_2 \cdot CuCO_3$	Malachite
	$CuSiO_3 \cdot 2H_2O$	Chrysocolla
	$Cu(OH)_2 \cdot Cu(C_2H_3O_2) \cdot 5H_2O$	Verdigris
Blue	$Cu(OH)_2 \cdot 2CuCO_3$	Azurite
	$CaCuSi_4O_{10}$	Blue frit
White	$CaCO_3$	Chalk
	$CaSO_4 \cdot 2H_2O$	Gypsum
	$Pb(OH)_2 \cdot 2PbCO_3$	White lead
Black	MnO_2	Pyrolusite

From the experimental work here reported, from that of previous investigators, and from the extant literary sources, chiefly the "Treatise on Stones" by Theophrastus of Eresos, our present state of knowledge concerning the individual pigments used by the Greeks in classical times may be summarized as shown in Table 4. Various mixtures of these pigments were also used. In particular, the iron ochres were often diluted with white pigments to produce lighter tints. There is no present evidence, however, that certain other of these pigments, such as cinnabar or orpiment, were ever mixed with other pigments for use. It is possible that future investigations may show that additional pigments or mixtures of pigments were known and used in ancient Greece.

In contrast to modern technological practice comparatively few pigments were in use, and of these only a small proportion were prepared by any chemical process. This indicates the primitive state of chemical technology in ancient Greece. On the other hand, certain of the pigments used there in ancient times are still among the most widely used and valued of all pigments, notably white lead and the iron ochres.

[12] RHOUSOPOULOS, O., "Beitrag zum Thema über die chemischen Kentnisse der alten Griechen," in P. DIERGART, "Beitrage aus der Geschichte der Chemie dem Gedächtnis von Georg W. A. Kahlbaum," Deuticke, Leipzig und Wien, 1909, p. 187.

[13] FOSTER, W., "Chemistry and Grecian Archaeology," J. CHEM. EDUC., 10, 276 (1933).

[14] *op. cit.*, p. 181.

[15] *op. cit.*, 57.

BY ANY OTHER NAME

Many a man has thought he was making a pun when he mentioned "Otto of Roses" instead of "Attar of Roses." As a matter of fact, there are two such terms in common use in the ancient art of perfumery. Otto of Roses is the essential or volatile oil of the rose obtained from the pressed leaf petals and often called "rose absolute." Attar of Roses is the same thing, with alcohol added to make a tincture.

Though surveys reveal that 85 per cent of all perfume buyers still prefer the aroma of the rose to the hundreds of other scents available, it does not always follow that the most fragrant liquid came from a real rose. Raw materials used in perfumes come also from animal and synthetic sources according to the American Medical Association. As many as 30 different materials are used to make a single scent.

Some of these materials are used for their odor value alone, some as fixatives—the ability to keep a perfume fragrant long after the alcohol has evaporated—and some for both purposes. The only four substances of animal origin in use are ambergris, castor, musk, and civet, and they are used primarily as fixatives. The essential oils are derived not only from flowers, but also from fruits or their rinds, roots of plants, and even the wood of some trees.—Ethyl News.

Demonstration of the Existence of a Free Radical

L. MICHAELIS

The Rockefeller Institute for Medical Research, New York, New York

THE following simple experiment is to demonstrate the existence of a free radical as a molecular species on an oxidation level intermediate between that of an organic compound of quinone structure and of the hydroquinone derived from it by reduction.

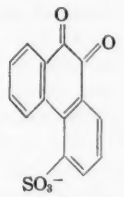
To 150 ml. of distilled water in a 250-ml. bottle, add 6 mg. of potassium phenanthrene quinone-3-sulfonate, 3 ml. of normal sodium hydroxide solution, and 0.4 g. of glucose. After thoroughly mixing, stopper the bottle and let stand. The color, originally pale yellow, gradually turns dark brown, then light yellow, somewhat more intensely so than originally. At room temperature the whole process takes about 10 or 15 minutes. Now open the bottle and admit air by shaking vigorously for about a minute. The twofold shift of color is reversed. On alternately shaking the bottle or keeping it at rest, the whole cycle can be repeated many times. The intermediate brown color is that of the semiquinone radical. In the presence of $CaCl_2$, even on using tap water instead of distilled water, an intensely green calcium complex of the free radical is formed instead of the brown compound.

The evidence for the statement that the brown compound is a free radical has been obtained from the measurement of magnetic susceptibility. The brown intermediate compound is paramagnetic, whereas both the initial and final compounds are diamagnetic. When present in higher concentration, two molecules of the free radical partially combine to form a dimeric compound which is no longer a free radical and which is in equilibrium with the free radical.

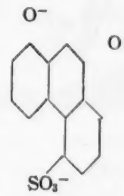
INTERPRETATION

The dyestuff, exposed to glucose in alkaline solution, is reduced in two successive steps which overlap to some extent. At the time of maximum brown color, about two-thirds of the total substance of the dye is present as a free radical. On exposure to air, according to the rate at which oxygen is admitted, the rate of re-oxidation by oxygen can be made greater than the rate of reduction by glucose, so the process is reversed.

Phenanthrene quinone-3-sulfonate ion has the structure I.[1] It is yellow, and in alkaline solution slightly yellow. On reduction, first one electron is added, producing the brown free radical. The structure of a free radical cannot be expressed by customary structural formulas with dashes, because each dash stands for a pair of electrons. In a free radical there is one unpaired electron which by its spin causes the molecule to be paramagnetic. So, omitting dashes, the free radical may be symbolized by II.



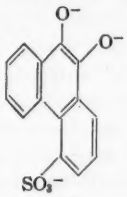
I



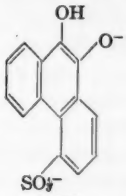
II

It is arbitrary to attribute the negative charge to the one oxygen atom. Rather is the structure an ambiguous one, the charge being with the same probability at the other oxygen atom. Such an ambiguity causes what is called resonance. According to quantum mechanics, it imparts to such an unsaturated compound a stability much greater than one might anticipate. The second step of reduction consists in the attachment of another electron, as shown in III.

According to pH, protons can be added to the negatively charged oxygen atoms. In the experiment as described, one proton is added, forming structure IV.

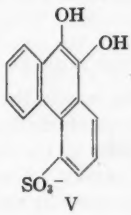


III



IV

In acid solution, another proton would be added to form V, which is the undissociated hydroquinone.



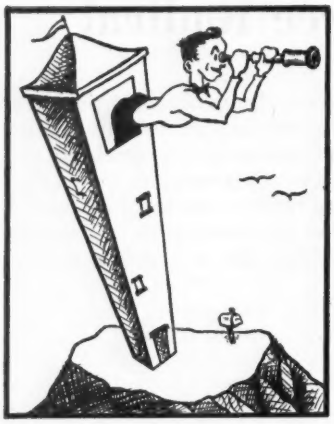
V

[1] The structural formulas given here do not give full account of the various structural formulas involved in the resonance but just demonstrate an ambiguity of the structure leading to resonance.

A Chemist Views AFRICA[1]

JOHN R. SAMPEY

Furman University, Greenville, South Carolina



FEW members of the chemical profession have had the opportunity to travel 40,000 miles over Africa. The Dark Continent was not included in the itinerary of scientists even in the early years of this century when it was considered quite the "smart" thing to go abroad for one's doctorate or post-doctorate training. Napoleon had, in the 18th century, carried a distinguished company of scientists on his conquest of Egypt, and the publication of their findings fills many a ponderous volume. North Africa was again invaded in 1942, and many members of the American Chemical Society, in one capacity or another, had the opportunity to observe, from the G. I. point of view, the countries of North Africa. It is doubtful, however, if the editors of our scientific journals will experience any rush of material from this 20th century invasion of the continent.

An I. G. (Inspector General) has much more freedom of movement than the average G. I. During my 19 months' service in Africa as I. G. for several commands, I visited all parts of the continent; and while my duties kept me largely with our own troops, I had frequent contacts with the military personnel of our Allies, and, through them, with European and native government and civilian leaders. Africa is so little known to most members of the Society that a few observations on its natural resources and industries may be of general interest. Authors of general chemistries may not feel at the conclusion of this paper the necessity of adding a chapter on Africa, but I believe the material recorded here will support the statement that Africa is destined to take an increasingly important place in the chemical markets of the world.

BRITISH GOLD COAST

My first tour of duty was in the British Gold Coast. Gold ranks second as a product of export, and the shops of the native goldsmiths in the capital city of Accra are most intriguing places to a metallurgist. The methods of refining and working the gold are very primitive, but the workmanship of the finished product is amazing. The skill of the artisan is such that a simple sketch of a design or a picture out of a Sears-Roebuck catalog is all he needs to make you any desired piece of jewelry or other object of the goldsmith's trade. The souvenirs picked up in these shops are among the most prized of any from an extended tour of four continents.

Gold ranks second to cocoa as a product of export. The Gold Coast is the largest cocoa-producing country in the world. For ten years before the war it exported over two-fifths of the world's supply. And the most surprising part of the industry is that it is operated and controlled by the natives. It is a challenging demonstration of what the Black Man can do for himself, for instead of being a product of big corporations like the rubber plantations of Liberia, the coffee plantations of Brazil, and the sugar industry of Cuba, the cocoa is grown on one-to-five acre farms of the peasants and exported by some fourteen different companies. European imperialists who preach that the native African has not developed to the point of maintaining his economic independence should study this cocoa industry.

The mining of manganese is rapidly becoming a leading industry, and this essential war material made Takoradi, British Gold Coast, an important port of West Africa. A narrow-gage railway which brought the ore down to the coast was served by railroad shops that would have done credit to a much larger rail system. It was a strange sight to see locomotives and boxcars being built in this small town surrounded on three sides by the forests of equatorial Africa.

NIGERIA

Nigeria is in many ways the most important country of West Africa. With its twenty millions of people it is the most populous of all British possessions, save India; and, like India, its people are demanding more independence, politically and economically. The vast natural resources of the country have contributed much to the war, as they found an outlet to Allied shipping through the port of Lagos.

Lagos is located less than two hours' flying time from Accra for the slow cargo ships of the A.T.C., A.A.F. A rail line connects this port with the rich interior of the country. The chief exports are tin, hardwoods, hides, palm oil, nuts, rubber, and ivory. One deposit of tin in the interior of Nigeria covers an area of 9000 square miles. Hardwoods are so abundant that they are used locally as we employ scrap lumber; many a G. I. was astonished to find 2 × 6 inch mahogany planks used in boardwalks or filling mudholes. The leather shops of Nigeria are unsurpassed on the continent; in them are

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

superbly tanned skins (all vegetable tanned) of both game and domestic animals.

BELGIAN CONGO

The mineral wealth of the Belgian Congo was a significant factor in the war effort of the Allied Nations. Half of the world's output of industrial diamonds (the black variety used as an abrasive) and one-third of the world's cobalt come from the Congo mines. Tin, copper, gold, radium, and uranium are mined in increasing quantities. History has been severe in its criticism of the manner in which the Belgian government has exploited the natural resources of this region ever since its wealth was laid bare by Henry M. Stanley's explorations. About ten per cent of the colony's total budget now, however, goes for public health work, and the Belgians have educated a large middle class of natives to serve as competent clerks, mechanics, railway employees, etc.

The Congo River furnishes the chief means of transportation in this land of tropical forests. This mightiest of all rivers, save the Amazon, is navigable for an estimated 14,000 miles, taking in its tributaries. Falls and rapids, however, interrupt this surface traffic, but in decades to come this potential water power may well be harnessed to make the Congo Basin a rich industrial region; Africa has 40 per cent of the potential water power of the world, of which two-thirds is in the Congo.

Leopoldville is the political and economic center of the Belgian Congo. Situated on the banks of Stanley Pool, it has a River Drive which is unsurpassed in its scenic beauty and the elegance of its palatial homes. While in the capital city I visited a cotton mill where there was so much American-made machinery that there was little difference in the process from that to be seen in any of the two dozen mills of Greenville, South Carolina, the textile center of the South. The Leopoldville mill was handling 150 tons of cotton a month.

SOUTH AFRICA

Viewed from a plane the geography of the Union of South Africa resembles more closely that of the eastern half of the United States than any found on the continent. Many of the rolling hills are wooded, and in the valleys are prosperous-looking farms and vineyards. Paved highways are more numerous, and connecting the larger towns are glistening steel rails. There are large areas, however, where development is retarded by insufficient precipitation, and the Kalahari Desert in Southwest Africa is as desolate as the Sahara.

Johannesburg is the Chicago of South Africa. Its fast-moving traffic, many industrial plants, beautiful park system, and youthful spirit, all remind one of the Windy City. It is the gold capital of the world. Year after year its mines produce more of the precious metal than the combined output of the United States, Canada, and Australia. Since 1932 the annual value of this wealth from the Witwatersrand area has surpassed 400,000,000 dollars, which constitutes 70 per cent of all the exports from South Africa. In sharp contrast to this mass of wealth, one finds on the outskirts of Johannesburg 300,000 natives living in the mine communities in stark squalor; their wages are so meager that they are constrained to live almost exclusively on the cheapest available carbohydrate, a maize or mealie meal. A recent scientific study of these unfortunate Bantu laborers revealed widespread incidence of deficiency diseases of many kinds.

The diamond mines of Kimberley are not so extensive as those of the gold fields, but they are no less interesting to the chemist. The mines are cone shaped, with the top dug out to a deep quarry; then the stem of the cone is followed down with a shaft for four or five thousand feet. The diamonds are recovered by a form of placer mining, while the cyanide process is used to separate the gold from the ore of Johannesburg. Where the blue clays associated with the diamonds come to the surface, large areas have been fenced off with barbed wire or covered over with concrete to prevent the finding of gems by trespassers.

RHODESIAS AND BRITISH EAST AFRICA

The British control one-fourth of Africa. A flight from the Union of South Africa across Southern and Northern Rhodesia, Tanganyika, Kenya, and Uganda will easily convince one who has visited other sections of the continent that here lies the best part for the White Man. The Rhodesias approach the Congo in mineral wealth: Southern Rhodesia produces gold, coal, chromium, and asbestos; the mines of Northern Rhodesia are rich in copper, lead, zinc, and cobalt; the largest cobalt mines in the world are in this province. The grasslands of this area support the largest herds of wild game to be found in all the world. Enough cotton is grown in Kenya to supply the entire British textile industry. Tanganyika, old German East Africa now under a British mandate, resembles Kenya in climate and vegetation; the chief products are coconuts, cocoa, sugar, tea, and coffee.

EGYPT

Egypt will take one back to the beginnings of chemistry. The word "chemistry" itself is of Egyptian origin, according to some authorities who say it is derived from *Chemi*, meaning black, and which was an ancient name for the country along the lower Nile. However that may be, the tombs of the Pharaohs preserved some of the oldest examples of the chemist's art and science. The huge blocks of stone of the pyramids themselves are held together by Egypt's notable contribution to cementing materials—namely, plaster of Paris.

The earliest samples of glass to which archaeologists can assign a definite date are some glass beads that were found adorning Egyptian mummies of the 17th century B.C. Samples of glazed pottery of a much earlier period have been discovered, but these beads are coated with what ceramists call the first true glass. The Egyptians became masters of the craft, and the glass establishments of Alexandria became world famous.

In the ancient city of Thebes there are stone carvings picturing the production of veneered and inlaid wood. In one group a strip of rare red wood is being glued to a yellow plank of sycamore. A pot of glue is shown heating over a fire. Another figure is seen applying glue to a board with a brush. These figures are at least 3000 years old, for the carvings date back to Tothmes III, the Pharaoh under whose reign the Hebrews made their exodus from Egyptian bondage.

Similar examples of the beginnings of chemistry could be multiplied from Egypt's storehouse of art and science. Modern Egypt is predominately agricultural, the one crop, cotton, accounting for four-fifths of the country's exports. The irrigation projects of the British have made the desert blossom like the rose. Reminders of ancient Egypt are seen on every hand through this farming section of the lower Nile: oxen tread at the mills; natives separate the chaff from the grain by tossing it into the wind; bricks are made as they were in the days of Moses; and boats are the same in design as those built by the Pharaohs.

NORTH AFRICA

North Africa from French Morocco to Tunisia is all too familiar to tens of thousands of American G. I.'s. We will conclude our round of Africa with just a word about Algeria, the most advanced of the Atlas States. The leading exports are wine, wheat, cork, fruits, hides, and wool. The mineral wealth includes 1,600,000 tons of iron mined annually, with lesser production of lead, zinc, and phosphate. Algiers and Oran are two ports which have been expanded tremendously during the war. Before the war Africa did not have a single port listed among the world's 50 leading harbors. The vast stores of raw materials essential to the chemical industries of the world, some of which have been indicated in this brief paper, should keep the ports of North, West, South, and East Africa burdened with steadily increasing tonnages long after the nightmare of 1942–45, which was the inspiration for this paper, is forgotten.

Analysis of Sodium Nitrite by Sulfamic Acid

A Gasometric Analysis

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IT HAS long been the opinion of the author that the student in the first semester of quantitative analysis should have an opportunity to deal with at least one precision-type gasometric analysis. The previous experience of the student with this type of measurement has probably been only in the laboratory of general freshman chemistry.

The instantaneous reaction between nitrites and sulfamic acid has been known for some time. Baumgarten and Marggraff[1] utilized this diazotization type of reaction for both gravimetric and gasometric estimations of nitrites. Their emphasis was placed more particularly on analysis of nitrites in the presence of nitrates. Gravimetric and gasometric data indicate an accuracy well within the limits generally prescribed. The reaction

$$MNO_2 + HSO_3NH_2 \rightarrow MHSO_4 + H_2O + N_2$$

suggests the gravimetric analysis by precipitation of the sulfate with barium ion and the gasometric analysis by measurement of the nitrogen evolved.

The entire apparatus is constructed by the student from material in his own desk or which is readily obtainable from the stock room. No little pride is experienced by the student when an apparatus of his own construction proves to be a precision instrument. The practice in preparing solutions of limiting reagents, calculations involving gaseous systems, manipulation of apparatus heretofore not familiar, and the use of the highly versatile chemical, sulfamic acid, were all points of worth-while benefit from a pedagogical point of view. An average section of students not under the author's supervision was given the set of directions, which are noted below, with highly satisfactory results. The time allotted for the construction of the apparatus and the determination was found to be less than that allotted to the more common analyses.

Samples of sodium nitrite for student analysis were prepared by the author, using weighed quantities of sodium nitrite dried at 110°C. and sodium chloride of analytical purity as a diluent. The samples are stable under ordinary oven-drying conditions, and an accuracy of 0.1 to 0.2 per cent may be expected.

DIRECTIONS

Introduction: For some years it has been known that sulfamic acid (HSO_3NH_2) would react instantaneously and quantitatively with nitrite nitrogen according to the following equation:

$$HSO_3NH_2 + NaNO_2 \rightarrow N_2 + NaHSO_4 + H_2O$$

Baumgarten and Marggraff[1] have utilized this reaction in two ways for the analysis of nitrites. A gravimetric method involves the precipitation of the sulfate by barium chloride and the gasometric analysis involves the measurement of the nitrogen formed. Since no reaction results from the treatment of a nitrate in dilute solutions with sulfamic acid, a useful differentiation between nitrites and nitrates is suggested from both a qualitative and a quantitative standpoint. Certain advantages of the gasometric analysis over either a volumetric or a gravimetric method are notable. No standard solutions are necessary, no indicator is needed, no weighed

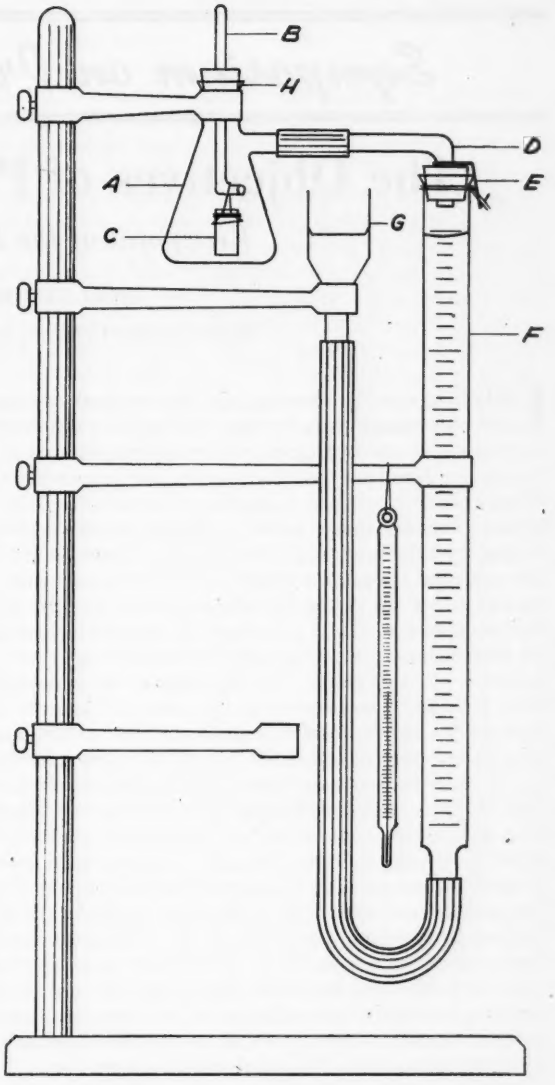
[1] BAUMGARTEN, P., AND I. MARGGRAFF, *Ber.* **63**, 1019 (1930).

crucibles are needed, and the apparatus for the gasometric method is easily prepared.

Procedure: Using the figure as a guide, construct the apparatus from equipment found in the desk or obtained from the storeroom. The reaction vessel *A* is a 250-ml. suction flask. Any larger size is not recommended. The rod *B* is a heavy glass stirring rod bent at the end to 90° to facilitate lowering the vial *C* (empty litmus bottle) to the bottom of the reaction flask. A solid stopper may be substituted at *H*, using the rod *B* independently as a lowering mechanism. A rubber band or a thin section of rubber tubing around the top of the vial will prevent slippage of the copper wire handle that is to be secured to the vial. Delivery tube *D* may be slightly constricted to fit the size 00 rubber stopper for the Mohr buret *F*. A tight fit of the 00 stopper at *E* may be assured by looping a rubber band around the delivery tube and securing it to a copper wire coil and hook around the buret. The leveling bulb *G* may be a Gooch funnel, ordinary funnel of at least 60-ml. capacity, or a separatory funnel. A light stopcock grease applied to the 00 stopper will be found advisable to prevent gas leaks. *Do not grease the stopper at H* since this may result in slippage of the stopper during the determination with an over-all change in volume of the apparatus. A check should be made for gas leakage before starting a determination. Lower the leveling bulb against a tight system, creating a low pressure within the apparatus. Constant readings of the meniscus over a ten-minute period will assure a gas-tight system.

Prepare a 50-ml. portion of sulfamic acid solution containing approximately 0.1 mol. A 10-ml. portion of this solution should provide at least twice the sulfamic acid necessary for a complete reaction with the unknown nitrite assuming 100 per cent sodium nitrite. The unknown should be dried for at least one hour at 110°C. Again basing the calculations on 100 per cent sodium nitrite, prepare a 250-ml. aliquot so that a 25-ml. portion will liberate no more than 45 ml. of nitrogen.

Pipet a 25-ml. aliquot of the unknown solution into the reaction flask. A 10-ml. portion of the sulfamic acid is then transferred to the vial and lowered to the bottom of the flask by rod *B*. An adjustment of the length of rod extending below the stopper may be necessary. The leveling bulb is raised nearly to the zero mark of the buret, the stopper *H* set firmly, and the leveling bulb so adjusted that atmospheric pressure exists within the system. The initial volume and the temperature are noted. The vial is upset by tilting the apparatus, and the solutions are allowed to mix. Slight motion of the ring stand will result in swirling of the solution in the flask. A complete reaction should take no more than a minute, as evidenced by no further evolution of bubbles of nitrogen. Since the reaction is exothermic, the slight elevation of temperature may be rectified by cooling the flask with a beaker of water which has been allowed to assume room temperature. The bulb is lowered slowly until the pressure is again



equalized and the temperature and volume noted. Make several readings over a ten-minute period to ascertain the establishment of equilibrium. Avoid rapid raising and lowering of the leveling bulb. (Why?) Since drafts of warm or cold air will cause errors, the apparatus should be so placed that this condition will be minimized. The use of the average temperature and volume readings will minimize this error.

The refinement of a jacketed Mohr buret may be added with very little trouble, but results of sufficient accuracy are possible without this if excessive temperature variations within the laboratory can be avoided. Run four or five aliquot portions, rinsing out the flask before each run. From data recorded and correcting for the vapor pressure of water, calculate the number of mols of nitrogen evolved, the weight of nitrogen, and the percentage of sodium nitrite in the unknown sample.

Symposium on Premedical Education

The Objectives of Premedical Education[1]

Viewpoint of the Liberal Arts College

WALTER B. KEIGHTON

Swarthmore College, Swarthmore, Pennsylvania

I WISH to start by showing why the medical schools and the colleges may be expected to have different viewpoints of the objectives of premedical education. To do this I will ask you to consider the processes by which a machine part, *e. g.*, a gear, is produced. (Why factory processes should come to mind in any discussion of educational procedures, I do not know. I am sure that I do not want too close a parallel drawn between factories and either the colleges or the medical schools.) In the production of the gear, factory *M* is concerned with its fabrication from some alloy or other engineering material. In this factory the gear blanks are prepared from the alloy, then machined, ground, and lapped to produce the finished gears, suitable to the purpose for which they were designed. Whether they are suitable or not depends not alone upon whether factory *M* has done its work well, but equally upon whether the alloy from which they were made had the necessary characteristics—*e. g.*, strength, durability against wear and corrosion—and whether it is capable of being fabricated into the desired form. Now the alloy is produced by factory *L*, which supplies factory *M*. Factory *L* produces numerous alloys, some suitable for gear wheels, some for fabrication into other final products. Its products require further processing or fashioning before they become usable; they represent an intermediate step between the raw material and the ultimate product.

In these respects there is some similarity between factory *M* and the medical school, between factory *L* and the liberal arts college. The finished product is the physician; the alloy from which he is fashioned is the premedical student prepared in the liberal arts college. Thus, the viewpoint of the medical school toward premedical education would be similar to the viewpoint of the personnel of factory *M* toward the operation of factory *L* which furnishes the alloy.

This may be illustrated by a set of parallel questions that factory *M* might ask about the alloy which serves as its raw material, and such as the medical school asks about the premedical student. "Does the alloy have such qualities that we can shape it according to our design?" asks factory *M*. "Has the premedical student acquired those qualities of mind which will adapt him to the educational process we use?" inquires the medical school. "Is the alloy strong enough to undergo the fabrication processes we have in mind?" "Does the premedical student have the mental and physical strength to carry him through the stress and strain of medical education?" And finally, one may ask about either the alloy or the premedical student, "Is this brightness merely a characteristic of the surface, or does it extend deeper?"

Factory *L* has a somewhat different viewpoint than factory *M*. While factory *L* (and the liberal arts college) wishes to produce the best product possible, it would be unwise for factory *L* to produce an alloy that could be used only by factory *M*, for there is no assurance that factory *M* will take the entire output. No, the alloy must have such properties that it will be adaptable to other uses than the production of gear wheels. In addition it may be observed that there is more than one alloy suitable for the fabrication of gear wheels and more than one method of producing each of these alloys. The correspondence between the consequent viewpoint of factory *L* and of the liberal arts college is obvious. It is my assignment to discuss the objectives of premedical education as they appear to one associated with a liberal arts college.

Let me begin by attempting to state the objectives of medical education as a whole. Briefly the aim of medical education is to produce competent physicians. We mean, first, competence in the special field of medicine, in the techniques of diagnosis and treatment, in the methods of preserving and promoting health. But beyond skill in the techniques and ability to use methods worked out by others, we desire that the physician understand the scientific background on which these techniques and methods are based. The competent physician must also have curiosity and imagination so that he may observe things that his predecessors failed to see clearly, that he may understand or even devise new techniques and new methods as he adds to his store of knowledge. If medical education can develop these qualities, the physician will continue to educate himself in matters scientific throughout his life.

But this alone will not make a competent physician. Flexner recognized this when he wrote in 1930: "It is

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

true that most physicians and most lawyers are mere craftsmen, it is even true that their training largely occupies itself with teaching them how to do things."[2] He adds that to state that medicine is a *learned* profession implies that its roots are "deep in cultural and idealistic soil." "Culture," said Matthew Arnold, "is the acquainting ourselves with the best that has been known and said in the world." A cultured person, having become acquainted with the best in civilized life of many ages and lands, acquires a fineness of taste. If, as a result of his knowledge, he sets up goals of perfection, of beauty, of excellence, he is an idealist.

The responsibility for developing skill in the application of the sciences to the practice of medicine is primarily the business of the medical school and hospital. The primary function of the liberal arts college is to provide a fertile soil in which culture and idealism may root and develop. This division of responsibilities does not exclude the nurture of culture and idealism in medical school nor the thorough study of sciences in the liberal arts college. It is, moreover, true that culture and idealism are not acquired solely by taking appropriate college courses. These qualities are developed quite aside from any formal studies, but their attainment can be encouraged and accelerated by suitable educational processes.

The aim of the liberal arts education, we have said, is to acquaint the student with the best that has been accomplished in the world, so that he may accomplish more through his own abilities and that he may support the efforts of others who happen to be favored with greater potentialities. This requires a knowledge of the history of the development of social institutions and ideas. The student must know what men have done and how men now live before he can see what men can do. Just as progress in medicine has been concurrent with a better understanding of the human body, its evolutionary development, how it functions, and how external factors influence it, so progress in human living must depend upon an understanding of the development of social relationships, how communities function, and how they are affected by their environment. The successful operation of a democracy—"government directly by the people collectively"—requires participation of all the people, and the responsibility of the most educated is the greatest.

Now it is true that democracy and good citizenship cannot be taught in any formal classes, but it is also true that for the most part the result of action in a particular situation is more likely to be beneficial if the action arises from an understanding of the nature of that situation than if it is the result of emotion or tradition. Therefore a study of the factors which have influenced the development of community institutions and governments can form a basis for intelligent efforts toward social betterment. One who is aware of the successes and failures of the past and of their causes is in a good position to act wisely toward the solution of the problems of today.

A concurrent aim of the liberal arts college is to teach the art of communication. Development in the student of the ability to write clearly and correctly is a concern of all college teachers, not only of those who teach courses in English composition. If the student is to translate his knowledge into action, he must translate his ideas into language that will convey his thoughts to other people. But I have in mind a two-way communication, not merely a broadcasting station. It is even more important that the student learn to read and understand books, for it is in books that much of culture and knowledge is recorded. This requires first that the student train himself to give his full attention to the written ideas, and secondly that he develop an adequate vocabulary. In this connection it should be pointed out that there exists a background of knowledge which should be common to all educated men, simply because it facilitates the communication of ideas. This common background of knowledge is used in speech and writing every day. Such phrases as "to cross the Rubicon," "remember Pearl Harbor," "between Scylla and Charybdis," or "a good Samaritan" each convey more meaning than several sentences. To be ignorant of this literary and historical background is a great handicap in the communication of ideas.

As a result of his study of the best in present and past civilizations the liberal arts student acquires a sense of values. There are many things in life which man has found to be good and which generations before us have also felt to be good. A feeling for what man has come to consider important and worth while, be it in literature or fine arts, in music or morals, is something to be acquired through a lifetime, but the student can make a beginning while he has the opportunity for encouragement and guidance and before his interests are crowded out by the press of professional obligations. The establishing of fineness of taste and high standards of moral judgment is important, for they control the sort of goal we set.

I would again emphasize that there is little profit in acquiring knowledge if no use is made of it. One of the principal aims of the liberal arts college is to encourage productive thinking. Productive thinking in any field requires the ability to see the basic issues, to sort fact from fancy, to think logically and clearly from the basic facts to a conclusion. Learning to do this requires both example and practice. Thinking in itself is a good thing, and the sport of facing and solving problems, including problems outside one's own field, adds zest to life.

I have as yet said nothing about the place of the sciences in liberal education. It is evident that a study of the sciences will contribute to the realization of each of the aims I have mentioned and that some knowledge of science is essential for the advancement of these objectives. Other participants in this symposium will very likely speak of this point and also concerning the particular place of chemistry in premedical education. They will undoubtedly have something to say about

[2] FLEXNER, A., "Universities, American, English, German," Oxford University Press, New York, 1930, p. 29.

the effect of the study of sciences in stimulating curiosity and imagination, in training in observation and clear thinking, in inculcating respect for facts, and as a necessity for the understanding of our environment. This much may be said for the place of science in the education of any liberal arts student. In the case of the premedical student there is an additional compelling reason for courses in biology, chemistry, and physics. These studies are the foundations of medical science, and a thorough understanding of their principles is requisite to the pursuit of medical studies. This is recognized by the American Medical Association which inludes courses in biology, chemistry, and physics as a part of the minimum requirement for admission to approved medical schools.

The science courses of the premedical student should deal with fundamental principles and not with the application of the sciences to medicine. Such specialized subjects as biochemistry, pharmacology, and bacteriology will be taught in the medical school. To teach these subjects in the premedical course will not preclude their repetition in medical school and will interfere with doing well that work which is the first responsibility of the liberal arts college.

Just as the properties of any alloy depend upon the properties of the phases of which it is composed and also upon the manner in which the several phases are associated or built together to form the aggregate, so does the final result of a liberal arts education depend upon the qualities of the various studies and extracurricular activities which compose it and upon the way in which they are built together within the whole college education. The trend in liberal arts colleges is toward a broad general education and away from excessive departmentalization in which elementary subjects are taught from the point of view of the specialist. Technical aspects of the subject, of interest only to the research worker, should be eliminated from the introductory course. But the liberal arts college must also provide relatively intense training in some one field of knowledge. Some of the work must be carried well beyond the elementary stage so that the student may fully appreciate what it means to study with rigor and thoroughness. Then does the student enjoy the experience of building upon his elementary knowledge and exercising his imagination and inventiveness to a fuller extent. The potentialities of the subject then become evident. By being pushed at times to the limit of his capacity, the student often learns that his capacity exceeds his own estimates and thereby gains confidence in himself. The premedical student usually does his intensive work in biology or chemistry, more rarely in some field outside the sciences.

There is a third component of premedical education. Time must be provided for deliberation, contemplation, and the acquiring of understanding. The student must be encouraged to take the responsibility for planning his own work and relaxation. Such opportunities will be rarer and such responsibilities greater as he proceeds to more advanced education and to a busy professional life.

As corollaries of a college education it is hoped that the student will develop curiosity to pursue his interests beyond the textbooks, learn efficient methods of study, and gain intellectual self-reliance. He should acquire open-mindedness and tolerance for the views of others and a sense of perspective which will help him to see his own field of specialization in relationship to the whole.

We should not expect too much from four years of education. Most teachers will agree that liberal education can be improved and made more effective than it now is. I think that it is already going through a process of change for the better. Its aims are being restated, its methods improved, and its importance reëmphasized; but what William Osler said 47 years ago about the study of medicine is equally true today concerning the liberal arts. He said:

> Undoubtedly the student tries to learn too much, and we teachers try to teach him too much—neither, perhaps, with great success. The existing evils result from neglect on the part of the teacher, student, and examiner of the great fundamental principle laid down by Plato—that education is a lifelong process, in which the student can make a beginning during his college course. The system under which we work asks too much of the student in a limited time. To cover the vast field of medicine in four years is an impossible task. We can only instil principles, put the student in the right path, give him methods, teach him how to study, and early to discern between essentials and nonessentials.[3]

All that can be hoped for is that, encouraged by his experience in college, the partly educated graduate will continue his studies of the liberal arts throughout life. The aim should be to stimulate the appetite and indicate how the hunger may be appeased, what fruits of knowledge are most satisfying and which have only a pleasing exterior but provide little nourishment.

I have read recently a review of Doctor Alfred E. Cohn's book, "Minerva's Progress." The review starts out this way:

> It is not common these days to find a physician endowed with a mastery of our whole rich cultural heritage, and a flaming yet critical faith in the possibilities of our democracy. The pressures on physicians being what they are, we have come to expect—and normally to receive—from them extraordinary technical proficiency and skill and little else. A reflective, thoroughly cultured, and educated physician is rare indeed; he belongs (we are told) back in the days of the general practitioner, when the slender demands of medical knowledge left time to reflect on human experiences and its lessons.[4]

"The pressures on physicians being what they are. . . ." Well, what are these pressures? Need they be? Must they restrict intellectual expansion? The first pressure is the urge to complete professional training at as early an age as possible. The premedical student spends four years in a liberal arts college and graduates, say at 22 years of age. After four years in medical school and a two-year internship he begins practice at the age of 28. If he wishes to become a specialist, he spends two to five years more in training and

[3] OSLER, W., quoted from an address to students at McGill University, 1899, in H. W. CUSHING, "The Life of Sir William Osler," The Clarendon Press, Oxford, 1925, Vol. i, p. 503.

[4] RANDALL, J. H., JR., in a review of A. E. COHN, "Minerva's Progress," *New York Times Book Review*, March 10, 1946, p. 4.

may be as old as 33 years of age when he starts to practice his specialty. It is easy to point out the undesirable consequences of this, more difficult to find a solution to the problem. Some urge a reduction in the number of years of training. I do not believe that the solution is to reduce the time spent in premedical education, for this would mean less of the liberal arts studies. The time for the physician to begin reflecting on human experience and its lessons is in his preprofessional years before the urgency of mastering techniques crowds out the time for contemplation of life in its broader aspects.

Many young physicians limit their practice to a specialty. These are the men who have spent the most time in training. Acquiring a high competence in a limited domain of knowledge is likely to encourage narrowness in other fields, sometimes even in those closely related. Both because it is in the nature of a specialty to put a premium upon the quantity of mental activity within a restricted field and because the press of that activity is likely to discourage the professional man from starting wholly new interests, it is important that the doctor be well introduced to the other fields of knowledge before he begins his professional work.

No educational system can make every doctor an Osler or a Cohn, but the qualities which we associate with such men are those qualities we should try to encourage in the premedical student and doctor. They represent a goal, not necessarily attainable for all, but nevertheless to be sought. The liberal arts curriculum is the educational scheme that strives to reach this goal. It may not be perfect, but it is the best we have. It is a four-year plan, and each year plays a part in the program. To take students into the medical school after completion of only the first half or three-quarters of the plan definitely involves a loss in their liberal arts education.

Apparently there is recognition in the medical profession of the desirability of four years of liberal arts studies preceding admission to medical school. While the *minimum* requirement for admission to medical schools as specified by the American Medical Association includes only two years of collegiate work for the development of the broad general interests of the student, it is true that most medical schools have set their minimum requirement in excess of this. In 1934 43 medical schools would accept students with only two years of college preparation, but five years later 66 out of 77 schools required more than two years of college work. In 1934 14.5 per cent of the students entering medical schools had only the minimum two years of college work, while in 1939 the proportion had fallen to 2.1 per cent.[5]

The desirability of more than the two-year minimum of collegiate work is stated in a recent study of Medical Education in the United States published by the American Medical Association.

> In view of the demands made on practicing physicians not only in professional duties but in civic and social responsibilities as well, some experience with the procedures of the senior college would seem to be desirable. The development of personal initiative, formation of independent judgments, initiation into research methods and library study as well as graduate study, for all of which the college curriculum should offer opportunities, favor the development of accuracy in observation, independence and solidity in reasoning, critical attitudes in reading, and judicious selectivity in the subject matter of study. All students who have had the advantages of extended collegiate study may not develop traits so highly desirable. Nevertheless, the student who has had four years of college has greater opportunities to develop than the student who with less educational advantage must depend largely on his innate endowment.[6]

Both humanistic and scientific studies help develop these desirable traits. It is usually evident to the premedical student that a thorough preparation in the basic sciences will make his work in medical school easier. The role of the humanistic studies is not always so evident to the student, and it is our task to stress its importance. The doctor treats man as an individual, not merely the man described in the textbooks on anatomy or physiology. The study of the activities, interests, and progress of man helps one to comprehend the individual man. Understanding precedes sympathy. The medical school oversees the attainment of "extraordinary technical proficiency" but the development of "culture and idealism" is entrusted chiefly to the liberal arts school. The latter should be emphasized, not because it is any more important than the former, but because it must early become well rooted in the intellectual garden or be crowded out by the rampant growth of professional education. Both qualities are equally essential to the truly competent physician.

[5] WEISKOTTEN, H. G., AND OTHERS, "Medical Education in the United States, 1934–1939," American Medical Association, 1940, p. 209.

[6] *Ibid.*, p. 68.

Chemistry in the Premedical Curriculum

The Viewpoint of the Medical College[1]

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IN A rapidly expanding scientific world the ever changing horizon requires that an ever changing viewpoint be adopted in considering what is good chemical teaching. New problems which are coming before us every day demand new approaches in their solution. Norman Cousins, in his recent book entitled "Modern Man is Obsolete," presents the problem not only politically and sociologically, but also scientifically, and demonstrates beyond question of a doubt that our thoughts and procedures of just yesterday are no longer of much avail in meeting our needs of tomorrow.

This is certainly as true in medical education as it is in any field of human endeavor. At a cost of millions of lives, the sacrifices of our young men, and the sufferings of the world population around the globe, new knowledge has been gained and new tools have been provided with which to fight disease.

Preventive medicine is probably among the outstanding benefactors in this respect with the development of DDT, the sulfa drugs, penicillin, sera and vaccine for the prevention of typhus, yellow fever, pneumonia, and influenza, with our greater knowledge and skill in the handling of dreaded dysenteries, the scourge of tropical and subtropical areas throughout the world, and with a more scientific approach to the major problems of sanitation in collaboration with the sanitary engineers in our armed forces. These, to mention a few, point the way to a broader, greater knowledge which will be of benefit to all mankind as soon as it can be made available to the general medical profession.

In surgery the developments have been outstanding. Witness the low mortality ratio among our troops during this war with a reduction to less than 50 per cent from World War I figures in the number of personnel lost through shock and wounds. The plasma proteins and their amazing contributions to the maintenance of blood volume and water balance in the human body following battle injuries is a chapter in itself and fundamentally is a problem in the physical chemistry of colloids. Orthopedic surgery, with the marvelous developments which have been realized in the techniques and manipulations of bone repair, the amazing use of the new drugs in preventing infection in wounds, plastic surgery, and the art of tissue restoration for functional as well as for cosmetic reasons, all will contribute to the welfare of mankind in the future.

The summary of our new knowledge is long and other discoveries should be mentioned—the new developments in malarial control and the great contributions that organic chemistry have made in this field; the delousing of whole populations of people, such as that so successfully carried out in Naples on arrival of our troops to prevent them from contracting typhus fever; outstanding developments in anesthetics and the techniques of anesthesiology involving the principles of chemistry and physics in their final solution; the use of the new hypnotics, such as barbiturate derivatives, in producing that state of semiconsciousness so necessary in obtaining satisfactory psycho-analytical data on those suffering from the emotional ravages of the war, be they soldier or civilian; the remarkable contributions of medicine, particularly the research medical sciences such as physiology, biochemistry, and pharmacology, to the study of aviation problems, involving as they do pure physics, pure organic chemistry, pure physical chemistry, pure quantitative chemistry, but more importantly requiring the mental capacity of trained individuals to correlate all of these fields of study into a composite whole in the final answer to be obtained through research. These constitute, in part, the new background of medical science.

Let us then look squarely at ourselves as teachers of medical students, and we imply by this term not only the instructor in the school of medicine, but also the premedical teacher who has the first opportunity to meet with the embryonic medical students when they enter college at the freshman level and who has the advantage and the privilege of guiding these young men's activities throughout their so-called premedical programs. Let us analyze, if we can, the problems we must face in preparing them better to serve this expanding world through better medicine in a great scientific age. We must discover just where our weaknesses are and try to overcome them by developing techniques in teaching and approaches to the student that will give us the result we so earnestly desire.

The analysis of the problem is relatively simple. These are some of the things we must endeavor to cover: (1) give better knowledge of the fundamentals and the broad principles of science, with especial emphasis on important new developments; (2) correlate the physical, chemical, and biological sciences to bring about a blending of the fields; (3) make of the courses we offer our students and information they gain therefrom actual tools in the hands of the student, to be carried with him throughout his life in the pursuit of medical knowledge; (4) instill in the student the spirit of research and adventure which is so fundamentally a part of all progress in any field of science; and (5)

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

instill in the student an appreciation of his responsibilities to society as a scientist, as a citizen, and as a benefactor of mankind.

These, to mention only a few, should be our aims in approaching each class we meet. If we fall short of attainment of any of these goals, the results in the aggregate will eventually be unsatisfactory.

Let us analyze for a moment just how some of these objectives can best be obtained, by giving critical consideration to certain of the scientific aspects inherent in the new developments of recent years.

The past decade has brought a new era in medication. More than ever, pharmacology, the science of drug therapy, has become chemotherapeutic. Much attention and hundreds of thousands of dollars have been spent in research on the sulfa drugs, morphine derivatives, the vitamins, and the hormones. This research has been directed toward isolation, purification, discovery of chemical formulas, and finally synthesis. Following this came the need for pharmacological and physiological testing of the new preparations, *in vivo* and *in vitro*. Many gradations of physiological and pharmacological effects were discovered. Only slight chemical modifications of the original substances as developed in the laboratory or isolated from naturally occurring sources have been found to exert profound effects upon the drug so far as its medical value is concerned. Literally hundreds of the sulfa drugs have been developed in the laboratories of the country, but only a few have stood the test of final chemical and biological assay. The same is true for the morphine derivatives, the vitamins, and the hormones. Small chemical differences cause great variations in pharmacological effectiveness. An example of this lies in the field of the sex hormones. Only slight changes in degree of saturation and location of the hydroxyl and carbonyl groups bring about the primary physiological differences between the male and female sex hormones.

For many years the metabolism of food stuffs, commonly known as the intermediary metabolism of the body, has been a knotty problem with much conjecture and few answers coming to light. The processes from digestion and absorption to the excretion of waste products are only partially understood. For instance, although insulin was presented to the medical profession in 1922 by Doctors Banting and Best of Toronto, it was only in March of 1946 that the actual function of insulin in the human body was made fairly clear. In between lie thousands of man-hours of research on the products of glucose as they occur in the human body and participate in carbohydrate metabolic processes through which these pass. Another example: new amino acids have been discovered, and nutritional experiments have demonstrated that some 10 or 12 of the known acids are essential for human growth and development, but the answer as to why these particular acids should be essential is still to be found. The problem of fat metabolism, if anything, is in an even more rudimentary stage. Even today the processes of absorption of fat are not clearly understood.

These questions continue to confront us. Why should relatively simple things, such as some of the amino acids, be essential due to a lack of ability on the part of the body to synthesize them, while in other cases far more complicated chemical compounds, such as cholesterol, are easily synthesized by the body and are not necessary as food constituents?

Recently the uses of radioactive elements and isotopes have entered the field of medicine. Remarkable use has been made of these tools in studying problems of intermediary metabolism and in helping to unlock certain of the hitherto closed doors in the field of liver function, blood regeneration, food storage in muscle and tissue, and growth and repair of the body. Recently the new techniques associated with radioactivity and isotope study have helped to answer, at least in part, the questions of synthesis of cholesterol by the liver, the life span of the red cell of the blood, and the synthesis of the hemoglobin which it contains.

Lives by the thousands were saved during the past war through the use of plasma protein, but very few who used plasma proteins knew how they functioned physiologically. From the treatment standpoint it is a very simple story, but from the standpoint of chemical and physical research the field is a very complicated one. We become involved in the pattern of the various amino acids as they occur in the protein molecule. We must discuss compounds with many carboxyl and amino groups in order to explain the acid-base titration curves for these compounds. Molecules containing as many as 200 amino acids may react quite differently if there is only transposition of the two terminal amino acids in the chain. Osmotic pressure relationships across charged membranes become a matter of concern. These answers must be found before the true functioning of the plasma proteins can be explained. The Donnan Effect, complicated as it may seem, must be discussed with the embryonic medical student if he is to understand just what is happening in the vascular system as a result of the presence there of plasma protein, a large nondiffusible molecule with a high surface potential.

With the development of penicillin, streptomycin, and other antibiotics, the chemist, the zoologist, and the bacteriologist have been drawn quite closely together. In this field of research so vitally important to all mankind, we find an absolute need for full cooperation among all the sciences commonly grouped together under the term "premedical." For instance, the formula for penicillin is fairly well known, although not absolutely proved. The present technique for obtaining penicillin is a long, laborious, and expensive one. How much simpler it would be if these compounds of such vital nature in the treatment of disease could be synthesized! But to date, although the federal government has put large sums of money into this research project and many commercial concerns have done likewise, the answer is not available. We must still depend upon the bacteriologist and cultures of molds to produce the vitally needed antibiotics.

Finally, the tools of this expanding science should be

mentioned. Although the buret, the pipet, and the balance will always be necessary in the pursuance of medical research, something new has been added. As vitally important for tomorrow will be the use of the mass spectrograph, the Geiger counter, the cyclotron, the electron microscope, and the chromatographic fractionating column. Professor Lafayette Mendel of Yale University frequently said to his graduate students, "Give me a new tool or a new method and I will give you a research problem of assured value." Never has this statement been more applicable than today, and the new approaches which have come with the new tools in the hands of scientists seem to follow the rule of cubes in number and variety.

The physician today walks hand in hand through the maze of disease with the chemist, physicist, zoologist, and bacteriologist in the solution of his problems. This being the case, the physician must be prepared to understand the implications of the new science of medicine; this means in turn that his foundation in basic sciences must be thoroughly laid prior to the time the student enters the medical school. It is absolutely true, therefore, that the student actually enters medical school when he enters the freshman year in college, and the premedical teacher is truly his first medical instructor.

A short discussion as to possible methods of approach is desirable, as well as some comment on what might be done by the premedical science instructor in meeting the challenge of the future. Certainly fundamentals must come first. The student cannot walk until he is able to crawl, and we cannot begin with the more complex aspects of our respective sciences until we have laid a proper foundation for the appreciation of the fundamental relationships in each of the sciences involved. One thing, however, can and should be done. Along with the A.B.C.'s should be given the reasons. A discussion of the elements in inorganic chemistry without introducing occasional glimpses into the romance of chemistry is unjustified. The teaching of physics as a cold mathematical science not only is an injustice to the student, but also to the teacher, who, if he would only do so, could cause a thirst for knowledge in the student if he were willing to discuss, occasionally and for brief moments, the applications of physics to the expanding needs of the expanding scientific world.

A few illustrations are given in emphasis of this thesis. Our courses in inorganic chemistry given to the freshman student give us our first opportunity to put into practice certain of the features of this new approach to chemical education for premedical students. It is certainly true that the day of transmutation is at hand. In a sense we are now all alchemists. The periodic table will not be limited to 92 elements. At least three new ones above uranium have been added, and decomposition of heavier elements will result possibly in the development of new "in-between" substances. Radioactivity and the concept of isotopes must be presented as part of the inorganic chemistry course of tomorrow. How thrilling it will be to the freshman students of next year and the years to follow to know that in their introductory course they are obtaining first-hand information on the secrets of atomic energy and that these are also related to the study of medicine. Certainly the fundamentals of inorganic chemistry must be given, but these should be presented in such a manner as to indicate to the student the application of the information he is receiving to the new chemistry which is developing. More attention will need to be given to C^{13} carbon, N^{15} nitrogen, C^{37} chlorine, P^{32} phosphorus. Electron cycles and atomic numbers will need to have greater emphasis than in the past, and effects of additions or subtractions of electrons, protons, and neutrons will need to be discussed as part of the freshman course to a greater extent than ever before.

In quantitative chemistry due consideration must be given to the new tools at hand. To be sure, gravimetric and volumetric analysis will always continue to be the subjects of greatest emphasis in the teaching of quantitative chemistry. It will be necessary for the student to master these techniques before he is able to go on with new ones. There should, however, be greater emphasis on electrometric and colorimetric techniques. The Mass Law must no longer be one of the mysterious secret possessions of the quantitative and physical chemist. Its application in the new medicine of tomorrow is almost universal. Treatment therapy using sulfa drugs is gaged by the level of the drug in the blood stream; physicians are discussing the mass effect of blood sugar as it pertains to the over-production or under-consumption theories for carbohydrate metabolism. All approaches to discussions of enzyme action, hormone control of physiological functions, and vitamin needs in nutrition are based upon inter-relationships associated with the fundamentals of the Mass Law. If possible, and mind you, we know we are treading on dangerous ground, there should be somewhat less of mathematics and somewhat more of application and visualization in the presentation of quantitative chemical material.

It is, however, in the field of organic chemistry that probably the major changes in teaching approaches will need to be made. We are prone to take what we consider the easy way out when actually a more stimulating way is available. We place a formula for acetic acid on the board and leave the impression that it is a picture of acetic acid. Is this true? Definitely not. Actually what we have done is to present a series of symbols which represent the chemical reactions of acetic acid, but in no sense of the word does the formula we use actually visualize the chemical molecule of acetic acid as it exists in nature. We say, after having given the relatively complicated formula for glucose containing six carbons, twelve hydrogens, and six oxygens, that this is glucose. Again we are wrong. In our meager way we are trying to express the idea of chemical reactions through which we know glucose will go under proper circumstances.

We impart to the student a sense of stability in organic compounds. We say that the carbon chain

is almost inviolate. We leave the impression that hydrogens are firmly attached to carbons and that oxygen bondings are only somewhat more unstable. Actually, the truth is that the whole chemical structures of glucose or acetic acid or any other of the well-known organic compounds which are used in the teaching of the junior students' are not rigid, but are in "dynamic equilibrium." Why not, therefore, explain to the students at the outset just what we are trying to do and not develop in the students' minds false ideas with respect to chemical structure? If they are to participate in the new science they must realize that carbon, hydrogen, nitrogen, sulfur, phosphorus, oxygen, and all other elements are loosely bound together through bonds which are actually not so difficult to break.

Transamination, transmethylation, labile carbon, hydrogen, phosphorus, these are all known and made use of in the new medicine. Conant of Harvard has demonstrated beyond question that radioactive carbon will appear in the carbon chain of glucose within a very few minutes if sodium bicarbonate containing radioactive carbon is given by mouth and nonradioactive glucose solution is injected intravenously. DuVigneaud of the Cornell University School of Medicine has shown that the amino acid methionine will give up its methyl group *easily* for the formation of creatine in the liver. Glutamic acid is now considered to be a carrier for the amino group and will make this group available to such things as pyruvic acid to form new amino acids in the body. Why, then, should we stick to rigid formulation in the presentation of our courses in organic chemistry? The teaching of a flexible organic chemistry will help to develop a flexible scientific mind in our students.

And again let us tread on dangerous ground. What are we teaching? Are we teaching students or are we teaching subjects? Are we going to continue the rigid inter- and intra-departmental divisions of science? Quantitative chemistry cannot be taught without relationships to general inorganic chemistry. Organic chemistry is intimately associated with all other fields of science. Circumstances alter cases. We cannot tell our students, for instance, that glucose is a nonelectrolyte under all conditions. Shaffer of Washington University, St. Louis, has definitely demonstrated that at least three of the alcoholic groups of the glucose molecule will ionize to given hydrogen ions, provided the solution is sufficiently alkaline. He has actually calculated the dissociation constants for these three ionizing hydrogens.

We all recognize the pride of possession a professor has in his subject and in the students studying under him, but this must be tempered with reason. All science teaching today is developing along patterns which have been necessary in medicine for a long time. In biological chemistry we do not discuss inorganic, organic, quantitative, and physical chemistry. We give the student the chemistry of the human body; in one lecture we may introduce all of the various chemical disciplines and also bring into the picture a discussion of the physical and zoological aspects of the subject.

The answer to the question propounded above is very simple. There should be inter-departmental seminars for our freshmen and sophomore students, *and even for the faculty*. Chemistry majors should know more about zoology; the zoology major must know something about physics, and the physics major should be encouraged to descend from his ivory tower. The University of Chicago has made certain attempts in this direction. Science orientation courses have been developed to give students the broad aspects of science not only with respect to what the sciences represent but as to what contributions each of the sciences will make in the world order. Divisions of Biological and Physical Sciences have been created and are offering inter-divisional opportunities for conferences and study. Major developments in the future teaching of science will probably be made along these lines.

You will note that there has been no emphasis given to the teaching of "premedical sciences." Such a term is misleading. The premedical student should be getting as much chemistry and physics, and this should be of as good quality, as that which is given to majors in the fields in which he is studying. Courses designed primarily for premedical students are usually substandard. There is likely to be a tendency to "teach down" to the premedical student. Medical schools are not interested in this kind of instruction. We must have men available for admission to our medical schools who are thoroughly grounded in all of the disciplines of science if they are to be able to grasp the full significance of the new medicine of tomorrow.

The above might indicate a desire on the part of the medical schools for more required semester hours in science for the premedical student. This impression is not intended or desired. We all recognize the need for a broad, fundamental education as the foundation for any pursuit in life. We realize that all of our students have at least a twofold purpose before them. One is to be a satisfactory and contributing citizen in their community and the national life. The other is to make the most of their abilities in the chosen profession in which they cast their lot. It is a well-known fact that a student who does excellent work in the scientific subjects of his premedical training and does poor work in the humanities does not make an entirely satisfactory medical student. One whose all-around training is of top quality is far more likely to succeed in his chosen profession of medicine.

The program as outlined above is going to take time. Many medical schools in the United States have already recognized this and are requiring each of their students to complete the baccalaureate degree before entering medical school. Many of the remaining schools will be coming to this decision in the near future. We wish to work hand in hand with the premedical instructors in these matters. We want them to understand that we are thoroughly sympathetic with their problems and that we are available at any time to give advice and *to accept advice* with respect to our mutual educational problems. Medical education, today more

than ever, is a continuation of the work of the premedical institution. A closer liaison and a better understanding of the fundamental aims and ideals involved will help in solving the problems confronting us.

Truly our expanding scientific world will demand new approaches in the teaching of science. As teachers in our chosen field it will be necessary for us to give the very best we have in developing the solution to the problems ahead of us. "Must we forever be drawing water from other peoples wells"? Will we allow tradition and interdepartmental jealousies to dictate our future course of procedure in science education? Let us hope not. We cannot keep our headlights on the past and our tail lights on the future any longer. Paraphrasing the title of Norman Cousins' book, we might say that "Modern Scientific Teaching Is Obsolete." Certainly some of it is. We must use our best thoughts and talents to correct this situation.

A final note regarding the aims in medical education is of great importance. In every class of students, whether it be premedical or medical, we must expect to find outstanding, satisfactory, average, and below average students. We must endeavor to give to each of these groups that which will qualify them best for the work ahead of them. Among graduating physicians there will be the general practitioner, the specialists in various fields, such as surgery, medicine, obstetrics, and psychiatry, and there will also be those who will contribute, through research, to our growing knowledge in medical sciences. Our plea as medical educators to our premedical colleagues throughout the country is for assistance in preparing students for the higher as well as the lower levels of accomplishment.

We are not justified in setting the qualifications and content of our courses to the tempo of average students. We must endeavor, not only through the presentation of high caliber courses, but also through personal contact, encouragement, precept, and example in research, to stimulate in our better students a desire to contribute eventually to the progress and development of new horizons in the field of the medical care of mankind. The goal is high—the rewards will be great.

The Scientific and Humanistic Objectives of Premedical Education[1]

Viewpoint of the Medical College

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TO DISCUSS my views of the scientific and humanistic objectives of premedical education would be relatively easy, but to discuss this topic from the viewpoint of the medical colleges is much more difficult. The members of the medical profession are a highly individualistic group and the colleges of medicine are widely different and nearly as individualistic as the men who direct them. I cannot speak for the individual medical school. I can only present what seems to be a consensus on premedical education as various medical college officials and educators have expressed themselves.

My point of view is affected by the fact that I am associated with a Department of Anatomy of a medical school and at the same time spend most of my teaching time with premedical students. We have the unique arrangement of teaching the premedical courses in comparative anatomy, mammalian anatomy, and embryology in the same department which teaches human anatomy and histology to medical students. Thus I have an opportunity to see both sides of the picture, so if my remarks are not entirely those of the so-called medical educator but also those of a premedical teacher like yourselves, you will understand the reason.

Regarding the objectives of premedical education, I am not obliged to limit my remarks to my opinions alone. Fortunately there are available statements by many medical educators to serve as our guides. During the school year 1944–45 Alpha Epsilon Delta Premedical Fraternity conducted a survey among medical and premedical educators on their views regarding a number of important problems in this field. In April, 1945, a Conference on Premedical Education was held at Union College in Schenectady. During the past ten years a large number of articles dealing with these same questions have appeared in various journals. These sources give us a wide sampling of opinions from many different schools and from many different points of view. I shall draw from some of these sources in my remarks.

The first question that arises in such a discussion as this is, "Just what kind of product is desired as a result of the premedical course of education?" If we can agree upon this question then we can proceed to discuss methods and results. The first question in the Alpha Epsilon Delta survey read as follows: "What are the fundamental or philosophical purposes of premedical education? Just what are we trying to produce? What are the characteristics of a desirable candidate for admission to medical school?"

Representatives from 41 premedical and 30 medical

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

schools gave replies to this question. A composite reply might read something like this: A desirable candidate should have good physical health, reasonably pleasing appearance, ability to learn rapidly and retain well, ability to gain understanding as well as facts, sincerity of purpose, ambition, industry, dependability, unquestioned honesty both intellectual and social, a sense of humor, a high degree of adaptability, sound moral character, sound training in the scientific method, adequate information in the technical fields of chemistry, physics, and biology, skill in languages and use of his hands, a broad general education generally referred to as a "liberal arts education," a sense of community responsibility and a knowledge of community problems in which he should sense his responsibility, a sound cultural and hereditary background, good judgment, and—mentioned by only a few—sound emotional development.

My remarks might end at this point. The qualities listed above are the objectives of premedical education, but obviously such perfection exists only in the ideal. Certainly no twenty-year-old *Homo sapiens* possesses all the characteristics mentioned. Yet we would all agree that those qualities are desirable; the question then is, "What is the minimum of these qualities the student *must* have to be considered qualified to study and practice medicine?"

I wish to discuss some of these qualifications further under three headings: first, the physical, second the intellectual, and third the emotional aspects of the candidate seeking admission to a college of medicine.

I would certainly agree that good health is essential for the physician both in training and in practice, but sometimes we confuse ill health with physical defects while ignoring more important things. I have known medical students who have completed the course of study in medical school while handicapped seriously. For example, I have known several who had only one leg, numerous color-blind individuals, a few with only one eye, quite a number who had contracted tuberculosis and after being cured became active and successful physicians. The most outstanding example of the physically handicapped physician is probably Dr. Carlson, a graduate of Yale Medical School, and himself a severe spastic, who now operates a large school and clinic for spastics in East Hampton, L. I. These are but a few examples to show that persons with sufficient other qualities may be successful in medicine even though the physical factor seemed to forbid the study of medicine.

It is in the field of intellectual attainment in preparation for medical school that we place our greatest dependence. We look for high academic marks, strong recommendations on academic ability, evidence of large knowledge in various fields—unfortunately, usually those closely related to medical subjects. In the field of the natural sciences and the methods of science the results are usually satisfactory and the selection of students relatively easy. Among the different fields of scientific training the palm must go to the chemists. I think there is no question but that the chemists have succeeded better in training premedical students than teachers in any other field of science. Of course the chemists have more time allotted to them than is given to any other field. I agree with the allotment because the organic and physiological areas of chemistry have developed so much in recent years that it would be impossible to teach up-to-date biochemistry in medical school without the time spent in preliminary courses. But there are certain disadvantages that arise from the fact that chemists are such good teachers of chemistry. The students are well grounded in chemistry and have the habit of exactness and the knowledge of specific qualities that identify specific substances. They have learned to describe by exact formulas what Nature does when certain conditions exist in the chemical laboratory. Often such students suffer certain handicaps when they enter a laboratory in biology—comparative anatomy, for instance. There they discover that in animals Nature seldom does the same thing twice; that each individual differs from all others, that no description of embryonic development or of adult structure will apply to all individuals of a species in the manner that the formula for making sodium chloride from sodium hydroxide and hydrochloric acid *always* describes that process. The student must learn the rules of science again—this time, that in *living* things, variation is the rule and that his judgment must be relied upon in interpreting his observations of Nature. In my experience students doing "A" work in chemistry are sometimes woefully weak in judgment though well informed in the facts of another science. Perhaps the chemists are missing an important point in education here, for of all things in medicine *judgment, based upon the facts of Nature* rather than the mere observation of the facts, is the most important. In spite of all the statements to the contrary, the practice of medicine is not a science; it is an art, the art of applying the findings of science and *of all other experience* to that most variable of all creatures—Man.

I believe that it is in the "experience other than science" that our premedical education is weakest. That I am not alone in this view is shown by the replies to another question in the survey mentioned above. The tenth question of that survey read as follows: "Do you feel that more of the 'Liberal Arts' subjects should be included in premedical education?" More than half of those replying to this question stated flatly that more liberal arts work is needed. This opinion seemed to be as definite from people in schools that require four years of college work before admission to medicine as among those requiring less premedical work. It is felt, more and more in recent years, that the physician of the future must be more broadly educated, that he must be able to take his place in his community as an intellectual and moral leader and know what he is talking about in more than just the field of medicine. It seems to me that underlying or resulting from this lack of broad education is the fact that so few premedical and medical students are really interested in *people* in the first place. This may seem strange and I agree that it is. Yet I have known very, very few students in medi-

cine who were genuinely interested in people as such. They were interested in medicine, they avidly assimilated the facts of anatomy, pathology, physiology, diagnostics, methods of examination and treatment; they learned to admire the "beautiful" case of brain tumor, of hypertension, of thyroid disease, but rarely did they learn or care to learn much about the person who was the "beautiful" case. Perhaps not being interested in the person who had the disease is a defense mechanism against damage to themselves psychologically. Perhaps it is the attitude that "if I look only at the disease it will be just a disease; if I look at the personality who has the disease my feelings will become involved." On the other hand it may be simply that they have been taught by men who themselves were interested in the disease but not the person. Students cannot be expected to reflect more desirable attitudes than their teachers.

My third point has to do with the psychological education or preparation for the study and practice of medicine. In this aspect of the individual, discrimination is much more difficult but also more important. It is in this area of the individuality that heredity and early family and other environmental influences have already left their mark. I refer to what the psychiatrists and psychologists call "personality." Personality means more than a pleasing appearance and social behavior. It is the inner person, the unseen by others and often unseen by self. Just as man has carried with him many prehuman structural features that are now important in medicine, so he has carried with him a much larger number of cultural and psychological features that affect his behavior and ultimately his health. All of us carry them in some form or other and to greater or lesser extent. These are the underlying motivations for much of our social and personal attitudes and patterns of behavior. These primitive forces or drives are compelling, are often unrecognized, and are often unsocial or antisocial in nature. Psychiatrists are finding this a greater and greater source of the ailments of mankind. Psychiatry is the most rapidly growing field of medicine, not because there are necessarily more people who develop mental disease but because we are just coming to realize the vast importance of mental and emotional factors in organic disease. To deal with these problems the student must have more understanding of the psychological causes of disease and a more sympathetic attitude toward those who are ill. To be able to do this he must have a wider and deeper understanding of human nature. This may to a large extent be gathered during his early years from his contacts with human life and emotions as seen in literature, art, history, philosophy, economics, and sociology. He needs to observe humanity in its cultural settings. He needs to grasp something of the vast interplay of forces in the social organism, to see motives—desires, loves and hates, frustrations—the constructive and destructive forces in action in society. This is too large a task to gain first hand. Therefore he must, and fortunately he can, gain much of this knowledge and understanding from the fields of study usually called "liberal arts" providing he has teachers who appreciate these things and who take the trouble to see, for instance, that the student reads "Othello" not only as good writing but also as a penetrating study in human love and hate, the two strongest forces in life.

I am frequently impressed with the fact that the exaggerated meaning of a word, a mere sound, may produce the most devastating states of mind and even mental disease. I believe we are just beginning to realize the importance of language itself in individual and community health. For example, think how recently have the names of the common venereal diseases become socially acceptable either in polite conversation or the press. How recently also has the word "illegitimate" begun to cease wrecking lives. Great numbers of neurotic and even psychotic persons have been made so by exaggerated brooding over something that has been called a "sin." Lack of emotional security, sense of inferiority, inability to accept failure, all contribute to human disease and suffering. The attitudes relating to these problems are formed early in life, and if better ones are to be formed, we must begin early also.

Especially is philosophy to be urged in the premedical years. If philosophy is taught as a record of how men have tried to relate themselves to the rest of the world, as attempts to solve the eternal problem of psychological or spiritual security, as methods of acceptance and adjustment to the world, then philosophy must become the most compelling study in all one's educational experience. For that is just what philosophy is, the philosopher's answer to his *own* sense of insecurity and smallness in this great universe. Each of us must solve that problem in some way at some time. Without education we accept traditional beliefs. With mental growth these often become inadequate; new reasons for being and doing must be found, and they must satisfy the inner desire to find security and a feeling of being of value in the universe. In the child brought up in emotional security in the family the adjustment to adult situations is usually readily found. But in all too many cases this is not so, with the result that various forms of frustrations, neuroses, and even psychoses develop as attempts at solution of this fundamental need.

All this means that the physician must understand these things if he is to serve his people fully. The first requisite to that is to understand himself. He must himself be emotionally mature. I would like to quote at this point two definitions of "maturity" which are clear and definite without being couched in the technical jargon of the usual psychiatric writings. One definition is from the book "Psychiatry in Modern Warfare" by Drs. Strecker and Appel, both of the University of Pennsylvania:

> Maturity is a quality of personality that is made up of a number of elements. It is stick-to-it-iveness, the ability to stick to a job, to work on it, and to struggle through until it is finished or until one has given all one has in the endeavor. It is the quality or capacity of giving more than is asked or required in a given situation. It is this characteristic that enables others to count on one; thus it is reliability. Persistence is an aspect of maturity; persistence to carry out a goal in the face of difficulties, unpleasant-

ness, discomfort, frustration, hardship. The ability to size things up, make one's own decisions, is a characteristic of maturity. This implies a considerable amount of independence. A mature person is not dependent unless ill. Maturity includes determination, a will to achieve and succeed, a will to life. Of course, maturity represents the capacity to cooperate; to work with others, to work in an organization and under authority. The mature person is flexible, can defer to time, persons, circumstances. He can show tolerance, he can be patient, and above all he has the qualities of adaptability and compromise. Basically, maturity represents a wholesome amalgamation of two things: (1) dissatisfaction with the status quo, which calls forth aggressive, constructive effort, and (2) social concern and devotion. It is morale in the individual.

In another recently published book, "Attaining Maturity" by Dr. Luella Cole, is this description of maturity:

> A mature person can come to a decision without having it bolstered up by friends, tradition, relatives, or authority; he can see that the tail goes with the hide, and he regularly applies this knowledge to his own activities; he can observe himself without being overwhlemed by prejudice; he prefers making a compromise to butting his head against a wall; he does not make up his mind in advance of the evidence; and he knows full well that he is not important.

Essentially, maturity is the ability to accept the world and one's place in it, not with indifference but with realism. It is the ability to meet life's problems, face them, struggle with them, and either solve them or find a way around them. Not to be able to accept life as it is must eventually drive one to the self-created world of phantasy, which is schizophrenia, or to suicide. Leading up to these final solutions are a multitude of neuroses with all the distressing physical and mental states related to them.

It seems to me that we *must* demand this kind of maturity of our future physicians. The complexities and uncertainties of our society are sending more and more people to their physicians with a large variety of symptoms which, if properly interpreted, are found to stem from the social structure and are reflected in the individual's health. The physician must be emotionally healthy himself; only then can he help others. Perhaps we cannot prevent young people's remaining immature; it seems now unavoidable that many young people fail to achieve full emotional maturity, *but we are not obligated to admit them to medical school and make doctors of them.*

Fortunately it is possible in most cases to detect the defective personality. Most intelligent laymen and any competent psychiatrist can detect the individual who is unlikely to reach full adjustment in his own life. The Rorschach test, used by a competent person, will give a most revealing picture of the personality. As one psychiatrist has expressed it to me, "It is like an X-ray of the mind." It seems to me that if this test is not used routinely on all applicants for medicine, it should at least be used on all doubtful cases—that is, where there is any doubt as to the personality qualifications of the premedical student. It should be used only by a psychiatrist, and the report should be simply favorable or unfavorable as regards admission. The test is so revealing that much that it shows should remain in the confidence of the psychiatrist. I believe also that if a student were to be admitted against the advice of the psychiatrist, the student should come under the observation and possibly treatment of a staff psychiatrist as soon as he enters the medical school, and his completion of the course be partly dependent upon the studies and recommendations made by the psychiatrist during the medical course. This may seem unduly severe, but I have seen medical students damaged mentally and emotionally during and sometimes *by* the study of medicine. I have seen some deteriorate into alcoholics, some into drug addicts, and several even driven to suicide. Cases such as these justify heroic measures with all questionable individuals.

Thus it seems to me that our purposes, our objectives, in premedical education should include three aspects of the student: (1) It should and must provide adequate education and training in the technical fields of the sciences. This is essential to enable the student to carry successfully the difficult program of the medical course. (2) His premedical education should also give him an understanding and appreciation of the world, its history, and its peoples. His science should not be a tool only, however necessary that tool may be. It should also contribute to his attitudes and his philosophy of life. From science he should gain not only skill but enjoyment, not only use but solace in the realization that in Nature there are no accidents, no whims of fate; that what he finds in himself or in his patient today is the result of what happened yesterday and not the gift of chance. (3) The premedical course of study should also be a period of study *of* the student, his adaptability, emotional stability—his "maturity" in another word—so that those developing satisfactorily and giving good promise of attaining maturity may be recognized. At the same time the frustrated, the emotionally maladjusted, the individuals with unsolved and perhaps insoluble problems of adjustment may be discovered and, if not provided with psychological treatment, at least be prevented from entering upon the study of medicine, later to provide another example of the emotionally blind leading the blind.

I do not know how long this educational period before entering medical school should be. Ideally it should be tailored to fit each individual student. How long it takes to establish the technical fitness to enter medical school can be determined by his course work. How long it takes to make a MAN in the full sense of the word cannot be prescribed. In some cases it will never come about. Those individuals must not be made into physicians. Whatever time is needed to prepare the student is worth while. It cannot take too long to prepare for the practice of medicine. It is a question of how much time we are willing to pay. In my view we should consider the product, not the time. If we develop the intellect but not the emotions, if we require information of our students but neglect wisdom, if we impart cold facts without the warmth of understanding, then we do not serve our society fully.

Chemistry in the Premedical Curriculum

Viewpoint of the College of Liberal Arts[1]

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AN ASSIGNMENT to discuss the place of chemistry in premedical education from the point of view of a College of Liberal Arts tacitly implies that the place of chemistry in premedical education may be considered from other angles too; however, in order to avoid weltering about in a morass of speculation concerning the variety of these facets, we may for simplicity observe at the outset that, in our opinion, the question of particular importance is, "What is the place of chemistry in premedical education in relation to the purpose of the practice of medicine?" Since the aim of the physician is obviously to maintain health or to restore it when lost or impaired, he should have at his command all the pertinent art and science that may be acquired, whether it come in a certain period of his training through the channels of a college of liberal arts, a school of engineering or technology, or any other type of educational institution. The original question then resolves itself into that of whether or not the proper amount of chemistry may be studied in a college of liberal arts without impairing the general program and purposes of this type of school. It is our belief that it may, and not with any weakening of its humanistic program but, on the contrary, with attendant improvement in strength and increase in significance.

In ancient times—and even today among primitive peoples—the powers attributed to the physician or medicine man and the arts and knowledge or science at his disposal were both oversimplified and simple; indeed, there was little of science in the true sense of the word but much of superstition and prayerful yet vain reliance upon black magic and incantations. Curiously enough, however, the abyssal failures of these methods for millenia have not sufficed to prove to multitudes of people the inadequacy and banefulness of such practices.

The relatively informed people (unfortunately a minority) among the billions on this earth have, however, irrefutable evidence of the power and value, not of chemistry alone, but of the scientific as opposed to the superstitious method. Opposition to science comes only from those who know little if anything about it, and it could well be disregarded were it not for the fact that they do not constitute a minority. A frontal charge from opponents of science is easily repulsed; the danger, as far as premedical education in a college of liberal arts is concerned, is more likely to be encountered in the superficially more plausible attack made to preserve a false division between humanistic and cultural studies, to which a sense of values and of the dignity of man is explicitly or implicitly reserved by their protagonists. Scientific disciplines, on the other hand, are pictured as cold handmaidens of truth, blind and unlovely, with no concern in or regard for the worthwhileness of man's existence.

Within the last few centuries—even the last few years—the advances in science have been so remarkable that it may be truly said that the physics, chemistry, biology, and medicine of the glorious ancient Greeks are now of only antiquarian interest; they were a part of the cultural childhood of the race. This observation is made in no supercilious attitude; no fault or stigma is implied and no pride of accomplishment or sense of superiority is assumed for us moderns, inheritors of legacies from the past. In many areas, but not in science, we can still learn much from Plato, Aristotle, and many another ancien tsource of wisdom, whose study we recommend to students, including the premedical students; but we are sure that if those Greeks of the golden fifth century before Christ—like Leucippus, Democritus, and a host of others—were with us today with their characteristic intellectual curiosity, they would still be wondering about the nature of things, still avidly seeking the latest information in what we call physics and chemistry. And, we think they would be continuing this search, not simply because they wanted a more luxurious garment of Nylon, perhaps, or a new plastic discus—acceptable and pleasing as such inventions would be—but also to derive deeper satisfaction in making possible fuller and better lives with sounder minds in sounder bodies.

Who among the ancient Greeks or, for that matter, who a couple of centuries ago, had any idea of the corpuscular nature of his body, of its wondrous assemblage of billions of minute cells that developed from one—or two? Who knew or even dreamed of molecules of water or of atoms of oxygen? Who, by the farthest stretch of imagination, ever conceived of protoplasmic entities, in turn constructed of molecules whose parts are atoms, largely empty space in which subatomic particles, common to all matter, living or not, move in their appointed rounds? Who can think on these things and their derivation from our star, the sun, without asking again the question, "What is man that Thou art mindful of him?" And if we ask this question, has not our study of chemistry brought us therewith to the very heart of humanism—what is man?

As far as the programs of colleges of liberal arts are concerned, we can see no incompatibility or inconsistency in increasing the amount of time to be devoted to the

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study of chemistry, provided that it be not done in a narrowly vocational way, a way which would be out of harmony with its vast reaches and its high place in the "many-mansioned house of philosophy." Let us remember that the curriculum in the Middle Ages leading to the degree of Bachelor of Arts was the *trivium*, comprising the three "liberal" arts—grammar, logic, and rhetoric; that leading to the degree of Master of Arts, the *quadrivium*, consisted of arithmetic, music, geometry, and astronomy. And let us not forget that modifications and innovations were not effected without prolonged dialectic. In those distant days chemistry was not recognized as one of the liberal arts; rather, as alchemy, it was considered a "black" art and not even respectable. We have all seen alchemists pictured working at their alembics and crucibles in dark and sometimes dingy rooms, a far cry from some of our well-built and splendidly equipped modern laboratories dedicated, as it used to say over the entrance to the old Kent laboratory at Yale, "to that science which ever invading the unknown, expands the domain of positive knowledge and preeminently ameliorates the lot of mankind."

Nowhere has the improvement of man's lot through chemistry been more striking than in its contributions to medicine. Indeed, in the matter of increased longevity alone, if this be counted a blessing, we heard but a few days ago that among the factors which make actuarial computations unusually difficult at the present time, the effect of the use of sulfa drugs is to be counted. It is obvious that present knowledge of and future advances in medicine are indissolubly linked with chemistry, a divination of the iatrochemists substantiated by subsequent generations. From the wealth of available illustrations of this we call attention, for example, to the rapid development of our knowledge of such physiologically important substances as sterols, vitamins, bile acids, sex hormones, cardiac aglycones, adrenal hormones, and carcinogenic hydrocarbons that followed the clarification of the structure of cholesterol a little over a decade ago.

Essential as chemistry and other sciences are to the development of medicine, we are not suggesting or implying that every physician is to be also a chemist, physicist, or bacteriologist. It is, however, necessary that the physician who is to have the power to grow in his profession have a share in the knowledge, techniques, and attitudes which can be had only as a result of training in these sciences whose rapid advances will be reflected in their applications to diagnosis and treatment of disease.

Indeed, these rapid advances in science are in themselves a source of our dilemma as to the nature of our premedical curriculum, for the student will need a proportionally longer time to become familiar with this expanding volume of knowledge. Even with the lengthened period devoted to premedical work, it still remains difficult to find time for many studies which are relevant, valuable, and, in the opinion of many, prerequisite to excellence in the practice of medicine. As things are now, the career of a physician can scarcely begin before the age of 30, a situation that may not be serious from a purely professional point of view but which surely is far from satisfactory from a social or sociological one. This condition is one that is difficult to remedy and which we shall have to continue to face. Of course, one way of coping with it is by the well-known and long-practiced method of division of labor—by specialization. This has been, and will doubtless continue to be, on the increase. Still, the premedical student usually does not know and frequently is in no position to know in what area, if any, he will specialize. Hence, there still remains with us the problem of choosing that minimum of work in chemistry most likely to prove adequate and satisfactory.

If this minimum of chemistry can be readily fitted into the premedical program in colleges of liberal arts together with the foreign language, English composition, American history, literature, philosophy, and other courses which are deemed essential to the culture of the fully rounded man, varying from school to school, then the problem is simple and, indeed, like the hypothetical perfect government, withers away. But the very fact that we are today discussing a problem which has been long a matter of concern and thoughtful study is substantial evidence that it has not yet been satisfactorily solved.

The American Medical Association once ruled, we believe, that a premedical student should have eight semester hours of general inorganic chemistry and four of organic chemistry. This regulation was later changed to a requirement of courses in general and organic chemistry without specifying the number of semester hours demanded so that premedical students may still fulfill this requirement by taking four semester hours of organic chemistry except in so far as this is modified by state regulations or those of particular medical schools. Furthermore, the state of Pennsylvania still retains the prerequisite in the form of eight hours of general and four hours of organic chemistry. This minimum clearly does not seem adequate to many, for numerous medical schools require other courses in addition, such as qualitative analysis, quantitative analysis, and physical chemistry. As a result of these differences in requirements, premedical students, who are acutely aware of the eager competition for admission to medical schools, attempt to implement their attacks on the gates with as many instruments of ingression as possible. The so-called cultural courses are then trampled upon in the melee and the ululating wails of mournful humanists rend the stricken air.

What then shall we do? Well, it was Socrates, we believe, who said that the unexamined life was not worth living. Hedonists would not agree, we are sure, and Socrates might have just come from a tilt with Xanthippe when he delivered himself so extravagantly; but we can go along with him to the extent of agreeing that progress comes from critically examining evidence upon which we base our premises so that, while holding fast to that which is good, we preserve and cultivate that elasticity or springiness of mind which will enable

us to escape from the rut or groove of stereotyped traditionalism.

More precisely, this means continuing, as far as our present purpose is concerned, what so many colleges have been and are now engaged in—namely, the study of curricula in order to see to it that they best serve the interrelated needs of our students and of society. These needs are so varied and so varying that we do not believe the best answer is to be found in any fixed curriculum. No one has sufficient wisdom to predict the future and to assert dogmatically what now is the best selection of studies, but it is our belief that it is to be found in the middle ground between freedom of election and rigid requirements. If, in sailing between this Scylla and Charybdis, we veer in one direction, we prefer the risks of freedom and for two reasons: first, because the offerings in any curriculum have already been put through a screening process so that complete freedom of choice is not wholly without restraint, and second, because students are thereby protected from impositions that come, not from intrinsic worth, but as a result of schemes whereby a particular course may be foisted upon them for ulterior reasons.

In conclusion we wish to say that the place of chemistry in the premedical curriculum in colleges of liberal arts should be such as to permit not only satisfaction of the present requirement of the American Medical Association, but also an enlarged one which should require at least six hours of organic chemistry. Also, a course in physical chemistry is so valuable that if it be not actually required as yet, it should be strongly recommended. Furthermore, whatever the desirability of chemistry may be in studying the marvelous chemical system within the human body it deserves an important place in colleges of liberal arts, not only from a vocational or utilitarian point of view, but also because of the peculiar contribution that it can make to a truly liberal education. Chemistry (with other experimental sciences, of course) in its objective search for truth lays continual emphasis upon the *criteria of evidence* and it is from this attitude, we think, that the surpassing achievements of science have come. We know of no better way to inculcate habits of critical evaluation than through instruction in rigorous induction from experiment, observation, and measurement. If superstition and prejudice are to be conquered, these are arms for the battle.

Scientific Values of the Humanities in the Premedical Program[1]

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WHEN a young man enters medical school he finds at once that every hour of the day and many hours of the night are consumed in the completion of a rigid and exhausting schedule of courses which leaves him very little time for extracurricular relaxation. In many cases such free time as he has will be devoted to the reading of detective stories or attending the local movie house. The intellectual demands placed upon him by the medical faculty are such as to leave him very little superfluous intellectual energy which he may devote to more serious pursuits. It therefore follows that any tastes for the humanities that are to be developed in him are best developed during his premedical years and the responsibility for this rests upon his college faculty. If an interest in history, art, or music is not aroused during college years, the chances are overwhelming that such interests will never appear.

The question will naturally be asked: If no such interests are aroused, what difference will it make? A taste for serious thought and serious reading contributes to the full life in the same sense that a taste for oyster and cognac adds to the pleasures of existence. But apart from these vague considerations, will a man be a better physician, will his diagnoses be more acute, will his therapy be more effective if he is versed in history and literature? To these questions I would answer unqualifiedly, *yes*.

The laboratory scientist derives his information from physical equipment and chemical substances with occasional recourse to the experimental animal. Whereas a knowledge of the humanities may make his life pleasanter, it need not, it might be argued, increase his effectiveness as an investigator. While it is a truism that many of our greatest laboratory investigators have extraordinarily broad interests, many examples of effective researchers with extremely narrow interests may be cited. The medical man, however, is faced with a totally different problem. The only ultimate source of information upon which the physician may rely is his patient, and it is up to him to elicit information from his patient by every technique and device at his disposal. Although it is occasionally overlooked, the fact remains that the patient is a human being, made up of problems, interests, and emotions, in addition to proteins, carbohydrates, and fats. If I may be permitted to include among "scientific values" an increased ability to collect pertinent facts by any technique whatso-

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

ever, then a grounding in the humanities, whatever its value to the laboratory worker, is of undeniable value to the physician.

During the four years in medical school a disproportionate amount of time and energy is devoted perhaps to the training of the student in performance and interpretation of the less personal procedures involved in medical practice. The student is adequately trained in the interpretation of a roentgenogram or a blood nonprotein nitrogen determination and, in many cases, comes to regard the diagnosis as the culmination of a wide variety of laboratory procedures.

A physician who limits his sources of information to those derived from the laboratory is a poor physician. Disease is much more than a collection of laboratory findings. A complete understanding of the patient requires that the physician appreciate not only the extent to which the psyche is contributing to the symptoms presented but also the extent to which the symptoms are affecting the patient's outlook and emotions. To evaluate these quantities which are often the dominant quantities, we have no laboratory procedures, and the only approach is to talk with the patient. The physician whose information is limited to the purely laboratory aspects of medicine finds himself in the embarrassing position of having nothing to talk about with his patient.

It is regrettably true that, at least in my limited experience, patients are much more willing to talk about baseball and boxing than about Indic philology or Gothic architecture, and it may be that the well-rounded physician should try to keep abreast of the times in these less cultural subjects; however, the reading of Boccaccio or Shakespeare, the study of Leonardo, or the experience of having listened to Beethoven will stand the physician in good stead. These were all men—they described and painted men—and it is the obligation of the physician to be acquainted with men, to deal with and diagnose men. Perfectly normal men in perfectly normal situations do not make interesting literature or art, as witness the large proportion of great literature dealing with the slightly abnormal. Some of our best descriptions of neurosis are to be found in the plays of Sophocles and Shakespeare, and the psychiatrist leans heavily on such authors for his source material.

Contact with the great authors, artists, and philosophers may give the student an understanding of man in general and his patient in particular which he cannot elicit from all the laboratory diagnostic procedures at his disposal. This very understanding may be of more significance therapeutically than all the drugs in the pharmacopoeia. The talent for such understanding is relatively rare, and when it is encountered in a doctor, that is likely to be a great doctor.

I have spoken thus far of the general benefits to a student of medicine of a sound cultural background. There are, of course, certain specific benefits that are sufficiently obvious as to require but passing mention. A reading knowledge of the important modern languages is of great value, and, I may add, is, in general, lacking. It is so bad that if, as a teacher in a medical school, I make so bold as to write on the blackboard a literature reference to a German journal, that is an occasion for an outburst of uncontrollable laughter among the student body. They know no German, and they are amused by that lack in their training.

The ability to write concise and precise English will be of use to the physician every day of his life. As every intern knows, writing consumes a large part of the doctor's time, and the more facilely he can accomplish this task, the easier his life will be. Judging by the examination papers which we have to correct, this particular ability is also not too well developed by the student body of many medical schools.

The degree of Doctor of Medicine carries with it, we hope, a little more dignity than does the title of Able Seaman or Certified Electrician. The ancient title of Doctor implies a teacher, a wise man, presumed to be a nucleus of culture in his community. As such, it is to be hoped that the physician is not totally ignorant of the history and literature of his art. The teaching of this subject should be the responsibility of the faculty of medicine, but to teach it to an audience completely uninterested in the subject of history in general is a very discouraging task.

In the usual first-year curriculum of a medical school the department which of necessity leans most heavily on the assumption of previous training is the department of biochemistry. In anatomy and physiology the faculties wisely assume practically no technical background, but we in biochemistry must take for granted that the student has at least been exposed to elementary inorganic and organic chemistry. In this assumption we are often disappointed, but curiously, in the long run, it seems to make little difference. It is my impression that the number and excellence of the college chemistry courses taken by the candidate prior to his admission to medical school will influence, to a great extent, the ease or difficulty with which he will digest our first-year biochemistry course, but will have very little effect upon his standing at the end of the fourth year and still less effect upon his skill in the practice of medicine. I do not mean by this to belittle the value of college chemical courses, for certainly we find it easier to teach biochemistry to students who have had a course in quantitative analysis than to those who have not. This is a transient difficulty, however, and after a year or more has very little influence on the course of the student. Such students who have a natural bent for science, who expect to enter an investigative rather than a clinical career, may derive great benefit from numerous courses in chemistry while in college. It is my belief, however, that for the majority of premedical students it would be well if they took no more than the catalogue requirements in the sciences and devoted the major portion of their college years to finding out how men have lived, what they have written and thought about each other, and how they have shaped the world in which we now find ourselves.

The Cultural Values of the Sciences in the Premedical Program[1]

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THE cultural values derivable from four years of study in a liberal arts course present an extremely complex picture. They are partly the result of the acquisition of factual knowledge, partly a growth of scholarly appreciation consequent upon contact with good literature, art, music, and other human accomplishments, and partly a development of intellectual curiosity and desirable habits of thinking. To all of these any study will contribute at least a little. The study of science necessitates on the part of the student the acquisition of much factual knowledge; it inspires an appreciation of nature; but its most valuable contribution is to the development of the ability to use the mind effectively.

The task which the authors have assumed is to discuss the cultural values of the science courses as part of the premedical program. They intend to show that the science courses possess certain definite cultural values which increase not only a man's satisfaction in living but also his potentiality for social usefulness and vocational success.

It is hardly fruitful to attempt to state in precise terms all of the cultural values of a college course or to place them in definite categories; nor can one separate those of the science courses from those of the nonscience courses. Both make their contribution to a balanced education. In a former symposium on premedical education arranged by Alpha Epsilon Delta, Dr. Victor Johnson[2] made this statement:

> The basic natural sciences provide opportunities for a liberal education fully equal to the social sciences or the humanities. Faraday's reports on his studies of electricity and Harvey's accounts of his experiments are no less exciting culturally than are the classics of English literature and poetry.

We agree with Dr. Johnson although, like him, we should not favor *replacing* the study of the humanities by the study of science. We hold rather that the study of science and the study of the humanities, together with other lines of scholarly effort, are complementary to one another in a modern liberal education. We find support for this point of view from another of the participants in this symposium, Dean William T. Caldwell,[3] who has said:

> Personally, I do not like to speak of chemistry and physics on the one hand and cultural courses such as those in Homer or Shakespeare or Wordsworth on the other. If we find in literature something of more significance than mere verbalism and the putting together of words beautifully, so, too, do we discover beauty and new meaning in the language of science.

The various fields of study, according to their nature, contribute in different ways and in different degrees to the over-all value of a student's college experience. His program must not, therefore, be over-specialized but should include courses furnishing a proper scholastic balance. The desirable breadth can be achieved only by having experience in all of the principal divisions of learning, regardless of the field in which the student's main interest lies.

The cultural values stemming from the premedical science courses which seem most outstanding are training in clear thinking and training in accurate observation. Along with these goes a certain associated value in the upbuilding of character. Let us examine these values in a little more detail.

In no field of college study does the process of reasoning from observed effect to probable cause and from known cause to observed effect receive so much emphasis as it does in the science courses. It is a constantly recurring experience both in class and in laboratory. As a result the mind gradually adapts itself to that type of reasoning. The student soon learns that to be successful in science he cannot indulge in "sloppy" thinking. Also, he learns to apply, in some measure at least, the *scientific method of philosophy*, the basic principle underlying all advances in modern chemistry, physics, and other sciences. He may not consciously study it and may not even hear of it under this title but, nevertheless, the inductive-deductive process becomes established in his way of thinking and finds frequent application in his later experience. This is the type of reasoning upon which the future doctor must rely in his professional practice. The doctor must be able to think clearly, to reason accurately, and to draw valid conclusions from the evidence at hand whenever a situation arises, as it often will, for which no formal part of his training can supply the answer. The extent to which a premedical student has developed this capacity in the course of his preparation may be taken as a valuable criterion of his suitability for a medical career.

Habits of observation, also, have cultural as well as professional values. In the laboratory work of biology and chemistry careful, often minute, observation of properties and effects is called for. The habit of close observation is not second-nature to everyone but can,

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

[2] JOHNSON, V., *Scalpel*, **15**, 9 (1944).

[3] CALDWELL, W. T., *ibid.*, **16**, 182 (1945).

in most cases, be acquired by first-hand experience. The possession of this habit, a consequence of experimental work, can hardly be regarded as culture in its abstract sense, but it has its cultural value in that it provides the raw materials for inductive reasoning. If the future doctor is to observe and evaluate accurately as symptoms such digressions from the normal as a patient may show, he must at least begin to develop his powers of observation in his premedical course. His success in doing this might be another criterion of suitability for a medical career.

Although the foundation of a man's character has been laid long before he enters college, even at this late date growth of character is still going on. Any influence which the science courses have on character development is well worthy of inclusion among cultural values. The study of biology, chemistry, and physics, requiring as it does the observation and accurate recording of experimental facts and data and the consideration of the precision with which measurements have been made, is certainly not without effect in engendering a regard for strict truth. Quantitative analysis and the laboratory work of physical chemistry have peculiar importance for this purpose.

The close association in the laboratory with his neighbors, both students and faculty, tends to develop a man's consideration for others, a capacity to give and take, a spirit of fair play, which is of undoubted cumulative value. A student who fails to show a proper response to such influences of his environment would be regarded as doubtful material for the profession of medicine.

The student acquires in his college science courses some appreciation of the social implications of science. He could not go through the premedical science courses without coming to realize how greatly science has aided in raising our standards of living and contributed to the physical well-being of man. He learns something of anesthetics, antiseptics, chemotherapeutics, X-rays, tracer atoms, the fluoroscope, radioactivity, and dozens of other things which not only have made life more livable but have so greatly extended the average life span. An alert student, the kind that medical schools want, needs little prompting from his instructors to make him aware of what has been done and what may still be accomplished in the interests of public health. The development of this spirit of working for the public weal has its cultural value.

Any given science course may yield much or little in the way of cultural values, depending upon how it is taught. It is our opinion that the science instructor should consciously guard against making his courses too highly specialized and too technical. He should see to it that they are taught so as to retain and even make more secure their place in a broad educational program. If science courses are based upon dogma and empiricism they have no place in modern education, liberal or otherwise. The memorization of facts, although essential in science, does not constitute education; developing the ability to make intelligent application of facts does, whether the user is a chemist, a businessman, an insurance salesman, or a doctor.

In planning a course in chemistry the two essentials which must be considered are *method* and *content*. Cultural values may be associated with both. Some so-called "cultural courses" that we have encountered put the emphasis upon content rather than upon method. These courses are taught by the "gee whiz method," extolling the wonders of science; they inform the student *about* science. However well such a course may enable a man to talk intelligently at the dinner table about matters scientific, the fact remains that it is of little or no real value, cultural or technical. Knowledge of the principles of chemistry and of the methods by which they were established is far more worth while culturally and, in the long run, vocationally as well.

We fear that in recent years there has grown a tendency to break away from the restrictions of the scientific method and to present important sections of chemistry in just such an empirical way. Knowledge of present-day ideas regarding atomic structure has its value; one can scarcely be considered an intelligent citizen today unless he can participate in conversation relating to the nucleus, the electron, and atomic fission; but it seems to us that instruction *ex cathedra*, even on atomic structure, is harking back to the methods of the medieval Aristotelian alchemists who accepted *authority* in preference to the evidence of their own senses. The flat statement that an atom consists of a positively charged nucleus with electrons whirling around it is culturally much less valuable than the same result arrived at by way of the historical and inductive approach. Incidentally, there is no more thrilling story in science than the succession of discoveries concerning the atom made in the last 50 years. It is only by following the development of ideas and principles that the student can evaluate them intelligently, and certainly the evaluation of ideas is an important feature of culture. The atomic theory, the kinetic theory, and the rest of the chemical principles underlying the establishment of atomic and molecular weights, formulas, equations, and valence, can and should be developed logically via the inductive-deductive method. A statement from the instructor that such findings are soundly based on the scientific method cannot be as convincing and as permanently satisfying to a student as the review of the actual steps leading to them.

The trend toward empiricism in the teaching of science may be due to a tendency toward increased specialization in the colleges. The values of the nonscience courses have been somewhat subordinated to the idea of technical training. The Engineering Council has realized this and has favored a restoration of some cultural education in the engineering courses. The college programs in chemistry approved by the American Chemical Society contain a sufficient number of the nonscience courses but probably could not continue to do so if the requirements were extended much further along technical lines.

This same trend has shown signs of affecting the

premedical program. The tendency seems to be growing to regard premedical students in the colleges as a group apart, following a predominantly scientific course. In many colleges premedical majors have been established. The premedical students often think that the main function of the college in their case is to give them a *training* in the facts and techniques of biology, chemistry, and physics which will fit them to carry on the specialized work of the medical school. They are inclined to over-load with science under the impression (which we hope is false) that this will facilitate their entry into medical school. Actual anticipation in the colleges of medical-school courses is not unusual in spite of general disapproval from the medical schools, the deans of which, as a rule, desire as candidates men who are *educated* rather than merely *trained*.

Our discussion of this subject is admittedly colored by our own experience. For a number of years we have been intimately concerned with premedical education. Results have been good, and consequently we believe in our system. We encourage our students to complete the four years' work for the bachelor's degree regardless of the published requirement of the medical school. What a student would miss in liberal education by leaving college before his senior year is not compensated by any gain due to earlier graduation from medical school. Most of us have been aware of the intellectual immaturity of the boys "accelerated" into medical school with a sparse two years of preparation during the war period. Their ability to *pass* their medical school courses has told only part of the story.

We have a Premedical Committee of the faculty which guides the premedical program, but we have no premedical major. On the contrary, we encourage the premedical student to choose his major field as any other student does, according to his scholastic interest. We require a minimum accomplishment of one course in each of mathematics, physics, and psychology, two courses in biology, and three courses in chemistry, including one-semester courses in quantitative analysis and physical chemistry. Thus, 12 full-year courses remain at the disposal of the student, of which never more than seven are needed to satisfy the requirements of Freshman English and the limited electives in foreign languages, the humanities, and the social sciences. We preach and try to practice liberal education for premedical students and leave most of the professional training to the medical school itself.

It is quite natural that many premedical students choose to major in chemistry or biology for the simple reason that it is in those directions that their interest lies. We feel that by doing this they do not sacrifice cultural values since they must take a fair proportion of work in the nonscience fields and since we strive to teach our science courses so that the cultural values will not be submerged in the technical.

APPLIED RESEARCH

The war has produced an unparalleled flood of scientific accomplishments. This progress was made possible by established fundamental scientific truths and the industrial research conducted prior to the war. The social significance of what research could accomplish was not lost upon the more imaginative writers of the prewar period. From then-known facts they fashioned a fantastic blueprint of the World of Tomorrow for their avid readers.

Then in one appalling moment those dreams became reality under the impelling force of atomic power. The pattern of the postwar world is now rapidly taking shape as applied research, promoted mainly by private competitive enterprise, makes available to the man in the street television, radar and jet propulsion, sulfa drugs and penicillin, plastics and man-made textile fabrics, and new metals of remarkable lightness and strength.

In these advancements the man in the street sees the proof of the dynamic power of research to influence his material and spiritual life. They will mean for him new fields of employment created by the development of new products and new uses for old products, improvements in existing goods and more goods at lower prices to satisfy his increasing number of wants.—Dyelines and Bylines.

Inner Complex Ions: A Chelate Species

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IN 1904 Ley (*1*) coined the name "inner complex salt" for the compounds typified by copper glycollate, for which he wrote Formula A (Figure 1). The name is apposite: *inner* connotes ring formation; *complex*, the presence of a secondary (coordinating) valence; and *salt*, the presence of a primary bond involving a negative group (in this case, $NH_2CH_2COO^-$) derived from an acid. He supported his argument by citing conductivity data for this compound in aqueous solution, its equivalent conductance being low and approximately independent of dilution. This evidence showed the concentration of cupric ion to be negligible and consequently proved the great stability of the ring containing the copper.

Formula A contains one type of chelate ring, there being many such types, as Diehl (*2*) has shown in a valuable review of these structures, which owe their picturesque name to Morgan (*3*). Diehl (p. 41) says: "The term 'inner complex' is frequently confused with the term 'chelate' in the older literature. As the unusual properties ascribed to the inner complexes are not characteristic of all chelate compounds but only of those which are at the same time nonelectrolytes, the term 'inner complex' must be reserved specifically for chelate nonelectrolytes." It is clear, therefore, that the two concepts in question are not synonymous. But it is questionable whether the broad reservation of the last-quoted clause ought to be taken literally. That it is being so taken is indicated by the following sentence from an important monograph (*4*): "According to Diehl, the term 'inner complex' should be reserved specifically for chelate compounds which are nonelectrolytic in nature."

The point is not merely academic, as a comparison of Formulas B and C, both taken from Reference 4, will show. On any basis the first formula is a chelate ring that is also part of an inner complex salt. The second contains the identical chelate ring; but, according to Diehl, it could not qualify as an "inner complex" because it violates the reservation under discussion—it is not a nonelectrolyte. To resolve the dilemma, let us read Diehl's quotation as it was no doubt meant to be read—namely, let us interpret "nonelectrolyte" as "virtual absence in the ionic form of the metal in the chelate ring." Since it is desirable to retain the concept inner complex salt, it would seem desirable to adopt the name "inner complex ion" for structures of the type formed by dissociating a positive ion or ions from Formula C.

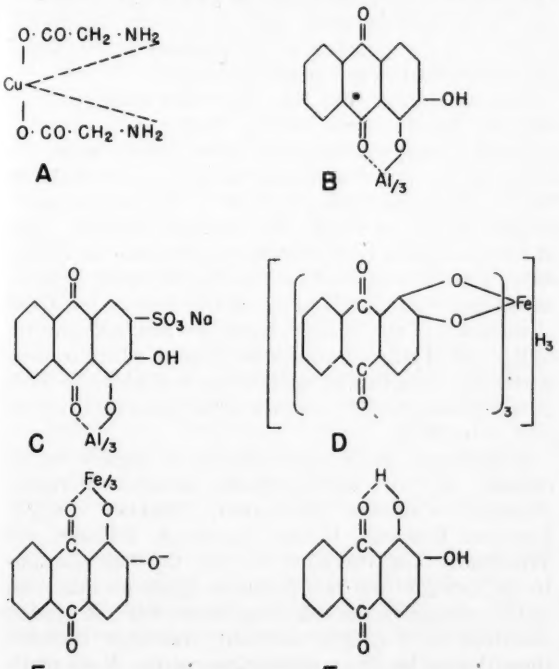

FIGURE 1. FORMULAS OF CHELATE COMPOUNDS. PRIMARY VALENCES ARE INDICATED BY SOLID, SECONDARY, BY BROKEN LINES (REF. 2, P. 40, FOOTNOTE 2).

Weinland and Binder (*5*) studied what they considered to be sodium, potassium, and ammonium salts of the acid for which Diehl (p. 55) has written (substantially) Formula D. The sodium salt of this acid was soluble in alcohol and in water, but stable only in the former solvent. The aqueous solution soon became discolored and decolorized rapidly if dilute; "alkalies" precipitated no ferric hydroxide from it, but acid decomposed the anion immediately, liberating alizarin. This experimental evidence points strongly to Formula E for the anion, which makes it an inner complex ion, in contrast with the comparable structure from Formula D.

Hüttig (*6*) proved long ago that the α-acid-hydrogen in alizarin is far the more firmly bound, the dissociation constants at 18° being $1.14(10^{-12})(\alpha)$ and $6.6(10^{-9})(\beta)$; this is due—as we now say—to the formation of a chelate ring through hydrogen bonding (Formula F). The argument in favor of Formula E may be summarized as follows: (*a*) Ferric ion, being derived from a transition element, seems even more prone than aluminum to form secondary (coordinating) valences and hence inner complex structures (*cf.*, Formulas B and C). (*b*) The chelate ring in Formula F is so stable that hydrolysis or decomposition by acid of inner complex

structures such as Formula E is to be expected. The second argument will be generalized below.

The mordant-dye lakes were first assigned structures analogous to Formula D by Liebermann (*7*) and structures analogous to Formula E by Werner (*8*). One is tempted to conclude that both structures are possible and to use stability toward strong acid as the criterion to decide which structure ought to be assigned a given lake, it being understood that any structure assigned on the basis of such intuitive evidence requires confirmation by the appropriate physical method. On this basis, the hydroxyanthraquinone lakes of zirconium or hafnium (*9*), which are unique in their stability toward hydrogen ion, would have structures patterned after Formula D, while lakes that do not show this stability would have structures analogous to Formula E.

SUMMARY

The name "inner complex ion," already implicit in the literature, is proposed for ions containing a chelate ring in which the metal is held by a primary and a secondary valence, and held so firmly that its ionization is negligible.

It is suggested that the extreme stability of the chelate ring formed through the bonding of the α-acid-hydrogen in hydroxyanthraquinones is the predominant factor in the attack of the mordant-dye lakes by hydrogen ion. Lakes readily attacked could have the inner complex structure suggested by Werner. On this basis, mordant-dye lakes stable toward hydrogen ion would not have an inner complex structure. Such lakes could have the "acidic group" structure proposed by Liebermann.

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Silliman College
of Yale University

SILLIMAN College is named for Benjamin Silliman of the Yale College Class of 1796 and Professor of Chemistry and Geology at Yale, 1802–1853. The college was completed in 1940. It contains new buildings of Georgian colonial style made of brick with stone trim, with the remodeled Byers Memorial Hall and Vanderbilt-Scientific Halls. Funds for the new construction and remodeling were provided from the bequest of Frederick William Vanderbilt, '76S. Otto Eggers and Daniel P. Higgins were the architects. The two stone dormitory buildings—"Van-Sheff" Halls—were built in 1903 (Wall Street) and 1906 (College Street) by gifts from Mr. Vanderbilt. Charles C. Haight was the architect.

Byers Memorial Hall was erected in 1902 by Martha F. Byers of Pittsburgh, Pennsylvania, in memory of her husband and her son, Alexander MacBurney Byers, Jr., '94S. Messrs. Hiss and Weekes were the architects. Remodeled in 1940, it became part of Silliman College. It contains the common rooms for both students and Fellows, the library, rooms for two resident Fellows, and the college kitchen.

Over the Grove Street gateway are cut the arms designed for the college. No arms appear to have been associated with the branch of the Silliman family from which Benjamin was descended. The principal charges in the college arms suggest "the elements of the an ient philosophers"—white field for air and water, red stripes for fire, green for earth—together reflecting the eminence of Professor Silliman as chemist and geologist. The acorns, a common charge in Dutch heraldry, were used as a crest by some members of the Vanderbilt family, and the establishment of the college was made possible by the bequest of Mr. Vanderbilt.

Silliman College, like the other nine undergraduate colleges, has its own library, dining hall, kitchen, common rooms, squash courts (five of them under the dining hall). It has accommodations for 250 students. The house of the Master is a part of the college quadrangle (corner of Wall and Temple Streets). The Master is Filmer S. C. Northrop, Professor of Philosophy, a member of the Yale Faculty for about 20 years. Associated with the Master as Active Fellows are about 15 members of the Faculty, some of whom reside in the college, all of whom have rooms there in which to meet students. Attached to each college is a group of Associate Fellows, mostly members of the Faculty, who take part in its affairs.

Sophomores, juniors, and seniors are eligible for admission to ten undergraduate colleges—Berkeley, Branford, Calhoun, Davenport, Timothy Dwight, Jonathan Edwards, Pierson, Saybrook, Silliman, and Trumbull. The freshmen live on the Old Campus. In the spring of the year freshmen apply for admission to the colleges in the following September. A student admitted to a college normally continues residence there during his three upper-class years. Each of the colleges admits to the privilege of membership a small group of nonresident students who are expected to take a certain number of meals in the college dining hall.

Science Teachers and the Atomic Bomb[1,2]

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THE atomic bomb is the dramatic symbol of the challenge presented to us by the development of scientific technology and by the present inability of mankind to control that technology for its best interest. That challenge faces all of us, but it is the student generation of today that must develop its life within the framework of the atomic age. Therefore it is imperative that the members of that generation should strive to understand the situation and to face it resolutely. We teachers certainly cannot do our students' thinking for them, but we can encourage our students to consider the problems.

In the present situation it appears to me that we science teachers, and especially teachers of physics and chemistry, have a golden opportunity and a special duty to arouse the interest of our students in some of the many problems arising from the development of the atomic bomb. The general nature and theory of the bomb itself is a fascinating subject that should be discussed in any course in general physics, but I think that we can and should give more than a mere exposition of the basic principles on which the bomb is based. The story of the development of this weapon provides a dramatic illustration of three important points about the nature of science itself that I believe should be brought home to students.

In the first place, the history of atomic physics since the start of the twentieth century very effectively illustrates the nature of the scientific method and the growth of scientific truth. Students need to get some idea of the nature of this growth and of the painstaking way in which discoveries are pyramided by careful study and exchange of information. Of course, the development of any major theory or branch of science provides an excellent opportunity to illustrate the growth of knowledge, but the history behind our present concepts of atomic structure is truly dramatic. An example that is frequently used to illustrate the scientific method is the controversy in the eighteenth century between the phlogiston and oxidation theories of combustion; however, Lavoisier, whose brilliant work settled the controversy, has been dead for over a hundred and fifty years, and students might well find this modern story more interesting and just as instructive.

In the second place, the development of the atomic bomb is an excellent but by no means a unique illustration of the international nature of science. I believe that in this day of national rivalries we science teachers should go out of our way to point out the universality of scientific truth and the international foundation on which it is based. Some patriots are trying to tell us that God gave us the bomb because we were the only nation that could be trusted with it. We must make it clear that the bomb is not an All-American Gadget, but is the outgrowth of research to which workers in Austria, Germany, France, England, Russia, Denmark, Italy, and many other countries made important contributions. There is no reason to believe that the American developments of the chain-reacting pile and the detonation of fissionable material should not be steps toward additional discoveries which we cannot even imagine now. I believe that these points should be stressed in any discussion of the bomb.

In the third place, I should like to emphasize the importance of the atomic bomb as an illustration of the impact of scientific technology upon society. Scientists are scientists primarily because they are afflicted with an insatiable curiosity. They want to know the truth about the universe in which they find themselves, and they are so concerned about this truth that they search for it without any regard for the effect which the new knowledge will have upon their fellow men. We as teachers should impress upon our students that the many questions to which we seek the answers do not exist in compartmented fields of knowledge but are all problems connected with how man can best understand and enjoy the universe in which he lives. The atomic bomb is the most dramatic illustration of the fact that, regrettable as it may be from the standpoint of pure science, the effects of scientific discoveries are so great that the scientists must be cognizant of these effects. It is very trite, but nevertheless true, to say that the so-called physical sciences, which seek primarily to interpret the behavior of inanimate matter and the lower organisms, have so far outstripped the so-called social sciences, which seek primarily to interpret human behavior and relationships, that we are faced with very serious difficulties in the application of technological advances. In fact, the discrepancy is so great that we are now able or shall soon be able to destroy our civilization unless we learn how to solve the social problems that beset us.

Up to now I have been talking about concepts that should be presented to all students. The success or failure of the coming generation will in large measure be determined by its ability to adapt itself to the unprecedented situations arising from large-scale technological developments affecting all mankind. Many of these developments and their attendant problems are already upon us; we cannot doubt that the future

[1] Address given before the Southern California Science Teachers' Association on February 16, 1946.

[2] Contribution number 1058 from the Gates and Crellin Laboratories of Chemistry, California Institute of Technology.

holds more discoveries and more problems. Therefore, every student who takes a course in science as a preparation for citizenship in the new world should sense the nature of the scientific method and the impact of scientific development upon society.

However, in addition to the students whose contact with science is confined to one or two courses, there are a few who have the interest and ability to go farther. In a recent cartoon a mother is saying to her son, "Why do you want to be a scientist; isn't there enough trouble in the world already?" Such a defeatist attitude cannot be condemned too strongly. Science is not evil, but the discoveries of science may be put to evil purposes; therefore, we should encourage our more able students in their desires to become physical scientists, but we should try to impart to them both a feeling of responsibility for interpreting their discoveries to the public and a social conscience about what is done with those discoveries.

I should like to go even further, and perhaps as a chemist I may be permitted to say something that you would not easily tolerate from an economist or a psychologist. I believe that it is very desirable that we encourage men with proper interests and abilities to go into the social sciences rather than into the physical sciences into which similar members of the past generation would have gone. I wish to make it very clear that I do not make this recommendation because I believe that men should be discouraged from entering the fields of the physical sciences; our civilization will obviously need an ever-increasing proportion of technically-trained men, and even the present supply is woefully inadequate to the demand; however, the very backwardness of the social sciences as opposed to the physical sciences emphasizes their need.

I am well aware of the sorry comparison that must be made at the present time between economics and chemistry. The social sciences do not have the background of accepted fact that is fundamental to the physical sciences. They do not even have adequate techniques for obtaining such facts; however, the difficulties are not insurmountable, and the growth of the physical sciences illustrates the power of concerted, logical, unbiased application of the human intellect to difficult problems. We cannot yet say how effectively men with a scientific background and outlook can attack the still more difficult problems of human relations, but it is my firm conviction that the application of the mental disciplines that have characterized the growth of the physical sciences can lead to the development of improved techniques in the gathering of data about social problems and can ultimately lead to solutions for some of the social ills that now beset us. Therefore, I believe that the present lack of any branch of knowledge that can rightly be called a science of human behavior and relationships should not be used to scare able young men away but should be thrown in their faces as a challenge. I ask you as teachers of the generation that must live with the atomic bomb to encourage your best students to face that challenge.

EDITOR'S OUTLOOK (*Continued from page 313*)

section of the JOURNAL, so other readers are not deprived of anything. It was hoped that similar arrangements might be made with other groups.

A reader comments:

> The magazine in its early days (the 20's) was much more valuable than now. Bring back some of the features of the good old days.

He should note, however, that in "the good old days" the JOURNAL did not have to pay its own way and that at one time a subscriber was getting for two dollars a periodical *which cost six dollars to produce.* The Chemical Foundation was paying the difference. But Santa Claus faded out of the picture in 1932, and from that time until 1945 it has been a long struggle to pull the JOURNAL out of the red ink. Now that this has been accomplished, we hope to give our readers the benefit by producing a better publication than we have previously been able to afford.

Another reader objects to the amount of space given to historical articles which, to him, have little interest. While it may be argued that chemical history has no necessary connection with chemical education, nevertheless, the JOURNAL is the official organ of the History of Chemistry Division of the American Chemical Society, to which we therefore have a real obligation. Furthermore, the JOURNAL is recognized (especially abroad) as one of the principal outlets for publication in the chemical historical field, and being proud of this reputation, we will try to retain it.

One reader answers the previous one's objection by saying:

> This journal is one of the few that contains any historical chemistry, and it furnishes a valuable outlet for articles of a historical nature. A real service.

After helping the Editor out in this way, the same reader touches one of the Editor's sore spots and the cause of many headaches.

> Perhaps I would suggest as the crux of the problem a more careful editorial selection to eliminate those articles of trivial nature or not of any lasting importance.

Would that we had the wisdom of Solomon—and a sufficient quantity of contributed material to exercise it upon!

Here and There in the Trade Literature[1]

FLUORINE, in relation to dental hygiene, comes in for discussion in the March *Dow Diamond*, as well as a direct-reading spectrometer which indicates the contents of magnesium alloys in less than 60 seconds and is therefore called a "mechanical brain."

● Anyone interested in the mysteries of the "Rh complex" would do well to read an article on this subject in the March *What's New*.

● *Monsanto Magazine* for April goes into the question of spectroscopic analysis in an article entitled "Tracing unknowns."

● Physical instruments for the analysis of oils and various compounds are becoming more and more common. No modern chemist can afford to be ignorant of these techniques. "Fingerprinting oils," in the March-April *Humble Way*, is a general elementary review.

● "Revolutionized is perhaps too strong a word but, even so, it comes pretty close to describing the insecticide business today. New developments that resulted from the necessity for better control of disease-carrying insects by the Armed Forces have brought about marked changes in insecticides now being made available for civilian use." An article in the March-April *Disc* begins with these words and goes on to describe new weapons for the war on insects.

● The following we quote from the last number of *The Chemical Digest* (Foster D. Snell, Inc., 305 Washington St., Brooklyn 1, New York)

SYNTHETIC RUBBER FACTS

Present plants will produce at least 1,100,000 tons in 1946. They cost $750,000,000 to build. That is an investment of approximately $700 for each ton of annual production. If amortized over 20 years with three per cent interest charged on capital investment, these plants would show a capital cost of just over four cents per pound of synthetic at the start, shading down to nothing in 20 years. Thus, at the projected selling price of 16 cents per pound of the product under peacetime conditions, the amount available for raw materials, repairs, overhead, and selling costs will start at around 12 cents per pound of product and increase year by year as the capital is written off. Yes, that's only one way of calculating. But with butadiene from petroleum at six to seven cents per pound, synthetics appear competitive with natural rubber. Now, call in the politicians.

Reports from experts who have recently returned from careful examination of German synthetic rubber plants and plans place the hurriedly constructed American industry well ahead of the older German one in quality of product, efficiency, and production.

For many important uses, rubber processors believe the various synthetics can never be displaced by plantation rubber, even at ruinous sacrifice prices. In other applications the future surely holds great promise for mixtures of synthetic and natural rubbers, also practically regardless of price. In still other applications the natural product will hold its place, according to informed opinion, even though it should cost ten cents or so per pound more than its synthetic competitors—an unlikely situation. In the first class fall many uses embraced in the category of mechanical rubber goods and solvent hose. Tires seem probable members of the second class although various parts of tires for different services will fall into both the second and third of these classes. Side walls of balloon tires still require natural rubber for best service.

● From *Dyelines and Bylines:*

Did you know that paints can deaden sound? It's being done by incorporating milled fiberglas fibers into the paint, the principle being that these fibers reduce vibration. The coming thing, we hear, for interiors of trucks, passenger cars, and other vehicles. Sorry, drivers, it doesn't quite muffle those mutterings from the back seat.

● *For Instance* (No. 21), a pamphlet "published now and then" by the American Cyanamid Company, reports results of experimental use of ion-exchange resins in sugar refining.

The present process of sugar refining involves "screening, filtering, precipitating some of the impurities by additions of lime, removing a portion of the lime by acidification, further filtering, evaporating, crystallizing, affination, remelting (or dissolving again in water), decolorizing, recrystallizing, and finally drying. Many of these steps are repeated two and three times in order to eke out the maximum quantity of our familiar white crystals before continued repetition becomes economically unsound."

The new process promises to be of value because of increased yield of refined sugar, higher value for recovered molasses which is suitable for human consumption as an edible syrup in place of the previously obtained "black strap," and savings in cost of processing.

In the new treatment, the raw sugar juices are passed successively through beds of cation- and anion-adsorbing resins. Concentration by evaporation of the purified juice, further concentration, and crystallization results in white table sugar and edible molasses syrup. The ion-exchange resins are regenerated by washing with mild solutions of acids, alkalis, and water.

Commercial trials of the process on a small scale both in Cuba and in California are gathering essential data using both cane and beet juice. No comment was made on the possible effect on the fermentation industries by cessation of a supply of "black strap" molasses.

[1] For the company and address of a magazine cited, see THIS JOURNAL, January, 1946, p. 38.

Out of the Editor's Basket

HERE are a few of the many wartime developments which have lately been released for publication:

Hydrogen

Methods for generating hydrogen from a sodium borohydride compound and water. It was found that sodium borohydride is readily hydrolyzed at a moderate rate by the addition of an acid-forming compound, such as boric acid, or by certain catalysts, such as cobaltous chloride. The heat of the reaction, per cubic foot of hydrogen, was less than when sodium or calcium hydrides were added. The resulting aqueous solution was mildly alkaline, and tablets of the compound could be handled safely with bare hands in open air.

Carbon Monoxide

A new method of determining carbon monoxide in air. Carbon monoxide reacts with mercuric oxide to form carbon dioxide and mercury vapor. An accurate determination of the amount of carbon monoxide in air was made by measuring the weight loss in the chemical reaction or by utilizing an instrument making use of selenium sulfide test papers. The length of the blackening produced on such test strips when exposed to mercury vapor, liberated by the reaction of carbon monoxide with mercuric oxide, indicates the carbon monoxide concentration.

Soap

A process for making liquid soap from surplus Napalm, the gasoline thickener used in flame-thrower fuel.

Sun Glasses

Sun glasses using a thin metallic film to create a gradient density of the lens. The metallic film is iconel, a chrome-nickel alloy applied to the finished lenses by vacuum evaporation.

German Developments

Reports from Germany tell of many interesting technical developments which took place there during the War. Here are some:

Esters for improving the lubricating qualities of special oils. Production of adipic and methyl adipic acid esters for use as lubricating oil components was stimulated by heavy demands for special oils to prevent machinery failures in the Russian winter campaigns. Most of the production was for aircraft lubricating oils, an adipic acid ester in 25 per cent solution being used for this purpose. Other esters were developed for use in oils for general lubrication on railway cars, weapon lubrication, and other purposes.

A method for igniting internal combustion engines without using spark plugs. The method, known as the "ring-process," was designed chiefly to eliminate spark plug fouling and ignition difficulties in aircraft at high altitudes. Ignition is effected by spraying a suitable liquid ether into the combustion chamber at the time of the compression stroke. The liquid ignites at the temperature of the cylinder and thus sets off the combustible charge. The process operates over the entire range of air-fuel mixtures and reduces knocking; however, an auxiliary set of spark plugs is necessary to start engines at low temperatures.

Cellulose ethers as soap substitutes, to save edible fats.

A process for production of cellulose acetate flake, requiring less acetic acid than is normally used, involving acetylation of beechwood pulp in the presence of a large excess of zinc chloride. The acetylation mixture consists of 950 kilograms of solid $ZnCl_2$ dissolved in 1780 kilograms of 100 per cent acetic anhydride and 1000 kilograms of glacial acetic acid. Sulfuric acid, commonly used as a catalyst, is not used in the process.

Fire extinguishers of the dry powder type, the mixture usually consisting of sodium bicarbonate (73.25 per cent), borax (25 per cent), kieselguhr (1.1 per cent), soap flakes (0.65 per cent), and traces of paraffin.

Addition of fish protein to viscose rayon to make it warmer and more wear-resistant. Viscose fibers made with 25 per cent of fish protein will take a crimp, like wool, resulting in a warmer fabric. The fiber can also be dyed with wool dyes.

Teacher's Fellowships

Union College has announced the establishment of the General Electric Fellowships for Teachers. These fellowships, which provide for tuition, traveling expenses, and maintenance during the six weeks of the summer session, are open only to experienced high-school teachers of science who are adequately prepared. The prospectus explains that:

> The program of study has been designed to enlarge each Fellow's grasp of recent developments in the phsyical sciences, rather than to make an immediate influence upon pedagogical methods. When he returns to the classroom at the end of the summer, freshly aware of the directions which the scientific adventure into the unknown is now taking, his teaching of fundamental principles will undoubtedly be inspired with new understanding and a spirit more likely to stir scientific ambition in the minds of his students.

Atomic Energy

A new booklet entitled "The World Within the Atom" has been issued by the Westinghouse Research Laboratories (Box 1017, Pittsburgh 30) to give science students a concise, easy-to-understand account of the recent developments in atomic energy.

Rustproofing

Calgon, Inc., has just announced a new low-cost rustproofing technique for steel and galvanized steel, known as the Banox process, which not only will protect metal during the manufacturing stages but will permit a tighter bond with paints and give it longer life through greatly enhanced corrosion resistance. The basis of this new chemical process is a flexible, glassy metal phosphate coating, so plastic that it will bend with the steel or permit die-stamping without harm to the coating. The coating, which has a thickness of from 5 to 15 millionths of an inch, may be put on by the spray, immersion, or brush methods. It requires no heat.

The process promises great improvements in the finishing of automobiles, refrigerators, gas and electric ranges, deep-freezing units, stokers, household appliances, and other metal articles. Greater finish durability and a longer service-life to the ultimate customer are assured.

First hit upon in 1942, the new process was tried out in giving a protective precoating for painted steel shell containers during the war. Formerly, the humid, salt-laden atmosphere of the Pacific stripped paint along with vital identifications from containers. In overcoming this, the Banox treatment was completely successful.

This process is described as a simple, effective, and economical method for producing a protective phosphate coating on steel, zinc, and other metals and alloys. Inorganic and insoluble, it actually is a plastic glassy phosphate coating. It is flexible and amorphous in contrast to the hard crystalline deposits obtained from phosphoric acid metal-treating processes. Relying on chemical rather than mechanical bonding, it holds organic finishes to the metal with great tenacity.

"Safety-Glass" Bottles

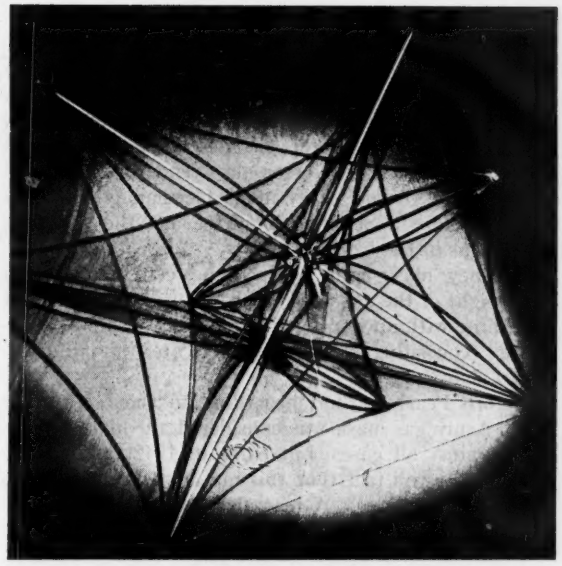
Tough nitrocellulose plastic-coated bottles in which corrosive liquids can be shipped or stored without danger of the liquid's leaking out if the bottle is broken appear to be the answer to one of the chemical industry's oldest problems.

The coating provides a protective armor around the bottle and holds its shape even though the glass underneath is shattered. This plastic coating is so tough that when test bottles containing sulfuric acid were thrown against a metal wall with sufficient force to break all the glass, the coating retained its shape and prevented the sulfuric acid from seeping through.

Victory?

A recent circular from the Bureau of Public Relations of the War Department contains the following, which we hope reflects official policy somewhere.

It is no longer enough to win a military victory alone. This past war began in the mind. It was finished, in the first stages only, on the battlefield. The final victory must be won in the mind. Ideas are weapons, not merely for war but for securing the victory.



(Courtesy of the International Nickel Company)

A RADAR REFLECTOR, ASSEMBLED AND READY TO BE MOUNTED ON A LIFE RAFT. THE PURPOSE OF THE REFLECTOR IS TO GIVE GOOD REFLECTION OF RADAR BEAMS TO ENABLE SHIPWRECKED AVIATORS AND SEAMEN TO BE MORE EASILY LOCATED AND RESCUED. LIFE RAFTS THEMSELVES, BEING MADE OF RUBBER, AFFORD VIRTUALLY NO REFLECTION OF RADAR BEAMS. THE MESH USED WAS KNIT FROM MONEL WIRE.

Carbon-White

The American rubber industry this year will use one billion pounds of carbon-black, an all-time high. Ever since 1911, when it was first used to give tire treads greater wear resistance, carbon-black has ranked along with sulfur and zinc oxide as the "big three" of the major compounding ingredients used in converting raw rubber into usable stock for all sorts of products. The poundage of carbon-black used in 1911 was one million, in contrast with this year's billion.

Discovery of a "white carbon-black"—a product of sand that gives rubber compounds the same qualities achieved through use of carbon-black but without discoloration—was recently announced. Ethyl silicate, a volatile liquid made from sand and alcohol, is burned and the white soot results. The superfine, white, partly translucent powder looks and acts entirely unlike the plain sand from which it is derived. Under the electron microscope its particles have the same size and shape as the superfine ones of carbon-black and perform exactly the same way in giving rubber compounds added tear resistance, abrasion resistance, and tensile strength without affecting the rubber's color or translucency.

Commercial utilization is still many months away because of high costs, according to W. S. Richardson, president of the B. F. Goodrich Chemical Company, the firm that will market the new material. Tires of baby blue, orchid, bright red, or any other color to match or contrast with the color of the car, will be practical. Rubber overshoes will not need to be black, but can come in fancy colors to match evening gowns.

Gas Masks

American soldiers had a gas mask so much superior to any used by the Axis that the enemy did not dare institute gas warfare, according to a recent report. The perfected mask was impregnable to all known gases, including the new secret gas described recently by Secretary of War Patterson as "rendering Japanese masks useless" and the famous German gas characterized before a Senate committee as "the deadliest poison gas in the world."

The new mask permitted a 50 per cent reduction in the weight of the gas mask canister by the replacing of soda lime with an improved compound—a new "whetlerite," consisting of specially activated and impregnated charcoal.

Before Pearl Harbor, according to the report, the U. S. Army gas mask was considered adequate protection against all gases, but early in 1942 research revealed the grim fact that this mask was vulnerable to certain deadly gases. Great alarm was aroused when the Germans were found to be accumulating large quantities of materials from which one of these gases could be made. The scientists then discovered through several months of work a special compound that would remove the gas. Army specifications were rewritten, and the new charcoal compound put into production. But the ink was hardly dry on the specifications when the Northwestern laboratory was electrified by the discovery that another extremely toxic gas was found to penetrate, under humid conditions of the tropics, all types of United States, British, Canadian, and captured enemy masks.

This news gave added impetus to the search for an all-purpose whetlerite and culminated in the discovery by Drs. Robert J. Grabenstetter and F. E. Blacet of the laboratory staff of a compound that was ten times more effective against the new gas. The laboratory developed a pilot plant to produce the new compound and within six months it was being made on a commercial scale and used in all American and Canadian masks.

LETTERS

To the Editor:

An article in the April, 1946, issue of your journal—"Let your librarian look it up" by R. R. Dickison—impels me to write to you, although it is not my policy to write to editors and publishers to comment on the contents of journals. But this article is so astounding that I feel it would be a great pity if it were acted on by your readers and if they were to assume that any such services as described by Mr. Dickison could be taken for granted.

May I digress for a moment to call attention to the realistic article in the same issue of your journal that immediately follows the Dickison contribution—"Wanted: More library chemists" by Else L. Schulze. Miss Schulze recognizes the difficulty in obtaining women (or men) with the training that is desired and suggests that "she should have at least four years of college training in chemistry," that "graduate work in chemistry will be very helpful," and that "the library chemist should also have a reading knowledge of German, French, and possibly Russian" and "a year of library science." Needless to say, it is difficult to find persons with this elaborate training, particularly at the small salaries usually offered in libraries.

This brings me back to Mr. Dickison's thesis. The first consideration is that very few chemical librarians have the training that is described as ideal for the work, and therefore they cannot possibly undertake the tasks that assume such training. And Mr. Dickison does not say that in the future ideal state of things, when all chemical librarians have this super-training, such services are to be required as he enumerates; but he suggests that chemists avail themselves of all these benefits now, when the chances are that the ill-paid chemical librarian has very little intensive training in chemistry and most certainly very little in the technique of abstracting which is a special field in itself.

But chiefly I take issue with Mr. Dickison in the matter of time. There are only 24 hours in a day, and most states have laws prohibiting a 24-hour working-day schedule. But Mr. Dickison lists 22 "services" of a highly technical nature that the chemical librarian is supposed to perform on request, and then as #23 "Order and circulate books and OTHERWISE MAINTAIN THE DEPARTMENTAL LIBRARY." (The capitals are mine.) My 30-odd years of library experience (none of them in a chemical library) point to the fact that Mr. Dickison's item #23 is almost a full-time job in itself and not merely an afterthought.

Perhaps Mr. Dickison means to suggest that the chemical librarian he describes will have a corps of assistants, but he does not say so; and as a practical matter, such is not usually the case. The being he describes, capable of performing the tasks he takes for granted, would be far beyond the human limitations of time, energy, and mental capacity—not to mention monetary compensation.

In suggesting the possibility of giving such services as Mr. Dickison enumerates, he places on many competent librarians the stigma of incompetence when such services are not forthcoming. This seems to me most unfair to a group of hard-working and usually under-paid men and women who sincerely try to give the best service possible consistent with normal training, intelligence, and the hours at their disposal.

HELEN BAYNE

NEW YORK UNIVERSITY COLLEGE OF MEDICINE
NEW YORK, NEW YORK

Selenium

CHARLES H. STONE

Vermont Junior College, Montpelier, Vermont

THE element selenium usually receives scant attention in our elementary textbooks, probably because it is of little importance commercially. Nevertheless, it is an interesting substance and well worth study.

Selenium was discovered by the Swedish giant among chemists, Berzelius. He was examining the sludge which collects at the bottom of the lead chambers in sulfuric acid plants. In the sludge, in 1817, he found a new substance from which he produced a hitherto unknown element. Just a few years before this, Reichenstein had discovered a new element which Klaproth named "tellurium" from the Greek, *Tellus*, the earth. Berzelius, therefore, named his newly-found element "selenium" from the Greek, Σεληνη, the moon. There is a very pretty myth concerning Selene as the daughter of Hyperion and sister of Helios (the sun) and Eos (dawn).

The element is not abundant, but it is found in various ores, such as clausthalite, a form of lead sulfide; lehrbachite, a lead and mercury sulfide; and onofrite, a mercury sulfide and selenide. It is also found in small amounts in other minerals, such as certain pyrites and chalcopyrites. In 1909 Warren discovered selenium in some meteorites, further proof that the occupants of terrestrial space are composed of the same materials which are found in our own planet.

Selenium is obtained from the flue dust of factories where sulfides are roasted, from the sludge of sulfuric acid plants, or most often from the sludge of electrolytic refining operations, such as the refining of copper or lead. The dry material from any of these sources is mixed into a paste with sulfuric acid and water and then boiled with addition of a little sodium nitrate, or, in place of that, a mixture of common salt and potassium permanganate, until the red color disappears. The selenic acid thus obtained is treated with fuming hydrochloric acid which produces selenious acid. The cold solution of this, when treated with sulfur dioxide, yields the red variety of the element.

Selenium is the sister element of sulfur, forming with tellurium the elements occurring in Group VI. It has an atomic weight of 79.2 as compared with 32 for sulfur. From the fact that the atomic weight is more, we may infer that selenium is less active than sulfur. Its valences are -2, $+4$, and $+6$, the same as those of sulfur. It exists in several allotropic forms, just as sulfur does. It will be helpful to remember that the two elements are very much alike in their chemical properties and so the reactions of sulfur are similar to those of selenium.

A piece of amorphous selenium is rather hard and quite brittle, just as sulfur is. The dark color of the element, the silver-gray coating on its surface, and the conchoidal fracture are characteristic. Another variety of the element is red.

The element readily combines with the metals, just as sulfur does, forming selenides. Let us grind some selenium to powder in a mortar. Take 10 grams of this powder and grind it with 7 grams of iron dust, a proportion of 80 and 56, the approximate atomic weight ratio of the two elements. The well-mixed material is poured into a dry test tube and heated. Ferrous selenide is formed, the action proceeding somewhat less vigorously than that between iron and sulfur. When the tube has cooled somewhat, we break it open and remove a gray-black product which much resembles ferrous sulfide. Selenium will unite similarly with zinc and with other metals such as copper and lead.

The element is both odorless and tasteless. It burns as readily as does sulfur, with a reddish-blue flame and the peculiar odor of horse-radish. In working with selenium, beware of the odor of its hydrogen compound; it is worse than that of hydrogen sulfide.

Selenium dioxide is formed by the combustion of the element. The dioxide is white and dissolves readily in water to form selenious acid just as sulfur dioxide dissolves to form sulfurous acid.

$$H_2O + SeO_2 \rightarrow H_2SeO_3$$

When selenious acid is treated with chlorine or potassium permanganate, selenic acid is produced; the process, of course, is one of oxidation, the reaction proceeding just as it would with sulfurous acid. Small lumps of ferrous selenide are transferred to a small flask connected to a train of bottles containing solutions of a number of different metallic salts, for example, those of cadmium, cobalt, nickel, arsenic, and antimony. Any excess of gas which may escape is led into the flue. Add some hydrochloric or sulfuric acid to the material in the flask, and presently hydrogen selenide forms and bubbles into the liquids in the various bottles. Various selenides are formed. The first time the author did this experiment he paid no particular attention to the escaping gas, but soon discovered that hydrogen sulfide was attar of roses compared to hydrogen selenide. So don't forget to take care of any unused gas. Burn it or in some other way consume it. At the end of the experiment pour in enough water to force all gas out of the flask before removing the stopper. Ferrous chloride or sulfate will, of course, be contained in the liquid in the generator and may be recovered if desired. If any escaping hydrogen selenide is burned, selenium dioxide and water are obtained, similar to the results obtained by burning hydrogen sulfide.

Place a solution of selenious acid in two small graduates. Into the first pass hydrogen sulfide and observe the formation of the beautiful yellow selenium sulfide. Into the second sulfur dioxide is passed, and the red allotropic form of selenium is precipitated. The equations are:

$$H_2SeO_3 + 2H_2S \rightarrow SeS_2 + 3H_2O$$

$$H_2O + H_2SeO_3 + 2SO_2 \rightarrow Se + 2H_2SO_4$$

The red modification of selenium is soluble in carbon disulfide, but the black variety is not. We recall the similar behavior of the various modifications of sulfur.

When the red variety of the element is heated, it changes to the black form. This reminds us of the change which occurs when yellow phosphorus is brought to its boiling point and a bit of iodine dropped in. On cooling, red phosphorus is found to have been formed.

Since selenium so closely resembles sulfur, could it not be used in place of sulfur? Sulfur is used in vulcanizing rubber; could selenium be so used? There are sulfur dyes; why not selenium dyes? There are facilities in this country for producing some 300,000 pounds of the element, but ordinarily a few hundred pounds are all that will be consumed. In wartime, however, the demand may increase enormously. In 1918 this country used about 200,000 pounds of selenium to replace manganese dioxide as a decolorizing agent for glass; such an occasion may arise again. Selenium colors glass red. It has few other important uses.

One curious property of selenium remains to be mentioned. The substance varies in its electrical conductivity according to the amount of light that falls upon it. We remember that sulfur is a nonconductor. An experiment shows that selenium differs in this respect. A selenium cell is connected to a relay and a single dry cell. The relay is also connected to a battery and a motor. In the dark no current is flowing. When a beam of sunlight or from a flashlight is directed against the cell, we see the arm of the relay close as the current flows feebly through the cell. The relay throws in the main current and the motor starts. This experiment illustrates the operation of automatic light signals which go off in the daytime and light up at night. This is valuable for lights at sea.

Under proper conditions selenium forms a colloid. One gram of selenium dioxide is dissolved in 500 ml. of water. To 50 ml. of this solution we add, after heating, 10 ml. of a one per cent solution of gelatin, and then, drop by drop, 60 ml. of hydrazine hydrate (1:2000 of water). Keep just below boiling for 15 minutes. The beautiful peach-pink color of the colloid is observed. The colloid can be made without the gelatin, but the protective colloid serves to prolong the life of the colloidal suspension.

The public press in July, 1935, contained accounts of cattle on the pasture lands of the northern mid-west which were being poisoned by the grass. The soil there contains selenium, and this is what caused the poisoning. The matter was investigated by the Bureau of Agriculture at Washington.

If you will experiment with selenium, don't be surprised if after a while your friends cross the street when they see you coming. The "selenium breath" which workers with the element soon acquire is most offensive.

Salt Shaker Wedding

ELIZABETH THOMPSON

The Junior College of Augusta, Augusta, Georgia

ON FRIDAY evening, April 13, at five o'clock, Miss Chlorine Halide became the bride of Mr. Sodium Alkali in a double beaker ceremony at the Little Church of Mother Nature. Rev. Electro Valence performed the ceremony.

The bride was given in marriage by her uncle, Mr. Argon Inert, one of the community's most prominent bachelors. The bride's eldest sister, Miss Iodine Halide, was her maid of honor. Misses Bromine and Fluorine Halide were bridesmaids; little Master Eka-Caesium was the ring bearer.

Mr. Alkali chose for his best man his brother, Mr. Potassium Alkali. Messrs. Lithium, Rubidium, and Caesium Alkali were ushers.

The bride was never lovelier than in her wedding gown of white cellulose acetate which blended perfectly with her blond beauty. The maid of honor wore a steel-blue-gray gown of viscose. The bridesmaids were gowned in reddish brown and yellow, respectively.

Following the ceremony, a reception was held at the Electrolytic Tea Room for the immediate family. Brine and carbohydrates were served.

The former Miss Chlorine Halide is a graduate of Anode High School and Electronic College, where she was a member of the Beta Ray Society. At present, she is connected with Valence's Mill where she is head bleaching agent.

Mr. Sodium Alkali is a graduate of Cathode High School and Cation College, where he was active in athletics, particularly swimming. Mr. Alkali has traveled extensively on land, sea, and in the air. During the war he had the honor of serving his country in the Army, Navy, Marine Corps, and Air Corps. In civilian life the groom holds a prominent position with the Electrochemical Metallic Company.

After the reception the couple left for the Great Salt Lake Region of the United States where they will make their home among their many friends.

Graduate Assistants

Their Stipends[*†]

ALEXANDER SILVERMAN

University of Pittsburgh, Pittsburgh, Pennsylvania

ABSTRACT

A STATISTICAL study of stipends for graduate assistants in leading colleges and universities. Of 97 institutions canvassed, 67 replied. Average stipends: first year, $77.77; second year, $81.13; third year, $87.65. Usual service requirement: 10 months. Average laboratory teaching requirement: 13.5 hours.

A statistical study of stipends for graduate assistants in leading colleges and universities was begun September 1, 1945, when questionnaires were sent to 90 institutions. Of these, 67 replied.

The figures indicated in the accompanying tables speak for themselves. It is not necessary for the compiler to make comments.

APPLICATION

Applying the results of this study, the Dean of the College, the Dean of the Graduate School, and the Dean of Research in the Natural Sciences have recommended to the university administration that beginning with the fall semester of 1946–47 a uniform stipend of $1000 shall be offered to graduate assistants in the natural sciences in the University of Pittsburgh for the college year of ten months, with nine months of service required. At the start, the graduate assistant will teach 16 hours per week and devote four hours to grading of laboratory reports and preparation for his teaching. As his service continues and he displays research aptitude, his teaching schedule will be reduced and more time will be permitted for research without a reduction of stipend. The individual may carry nine credits per semester of graduate studies toward an advanced degree. He will receive an annual tuition allowance of $180, unless it is otherwise provided for. Also, unless otherwise provided for, he will be exempted from the payment of laboratory fees, apparatus, and supply costs.

The statistical study, with the application of the findings in the University of Pittsburgh, may prove helpful to other institutions.

* Contribution number 586 from the Department of Chemistry, University of Pittsburgh.

† Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

School	$ per month: Year 1	Year 2	Year 3	Number months	Tuition allowance	Fees exempt	Lab hours	Grading hours
1	75	75	75	10	Yes	No	15	
2	95	95	95	10	None[1]	Yes	12	
3	80	...	...	9	None	No	12	Yes
4	90	90	90	10	300	No	10	
5	66	66	66	10	Yes	Yes	12	
6	75	75	75	10	250	No	12–18	
7	75	75	75	10	None	Yes	13	
8	100	100	100	10	Yes[2]	...	15	Yes
9	35	40	40	10	Yes	No	12–15	
10	120	120	150	10	Yes	Yes	12	Yes
11	75	75	...	10	200	Yes	15	
12	83–92	97	103	10	None	No	12	
13	60	...	...	10	12 Crs.	No	15	
14	60	60	...	10	Yes	Yes	12–15	
15	30	30	30	10	142.50	Yes	12	
16	125	125	125	10	None	No	20	
17	75	75	...	10	Yes	Yes	16–18	
18	100	100	100	8	Yes	Yes	12	
19	76.50	76.50	76.50	9	Yes	Yes	12	
20	60	60	60	10	130	Yes	12	
21	60–70	70–80	80–90	10	No[3]	No[3]	16–20	
22	75	75	75	10	200	Yes	12	Yes
23	60	80	80	10	Yes	Yes	12	
24	75	75	75	10	None[1]	Yes	18	
25	100	100	100	10	No	...	12	Yes
26	97.77	97.77	97.77	9	Yes	Yes	15	
27	83	83	110	9	None[1]	No	12–15	
28	80	80	80	10	300	Yes	7	
29	60	60	60	10	Yes	No	12	
30	60	70	70	10	Yes	Yes	15	
31	70	70	70	10	350	Yes	12	
32	93.85	93.85	...	8	150	Yes	15	
33[4]	60–80	60–90	60–90	10	Yes	Yes	15–20	
34	75	75	...	10	None	Yes	18	
35	75	75	100[5]	10	100[6]	Yes	15	
36	66	91[7]	...	10	None	Yes	15	
37	80	80	80	10	Yes	Yes	12	
38	112.50	112.50	112.50	10	200	Yes	12–15	
39	50	62.50	75	10	180	Yes	16	4
40	100	100	100	10	None	No	20	
41	100	105.50	111.11	10	450	Yes	8–10	
42	100	109	119	10	Yes	Yes	12–15	
43	100	100	100	9	240	Yes	12–14	
44	50	50	60	10	180	Yes	16	
45	93.75	93.75	93.75	8	None	No	10	10
46	93.33	93.33	106.67	9	None[8]	No	16	
47	50	66.67	66.67[9]	12[10]	None[1]	Yes	18	
48[11]	88	88	88	10	None[1]	No	12	8
48[12]	100	120	120	10	None[1]	No	12	8
49	80	80	80	10	Yes	Yes	15	
50	30–40	45–60	70–90	10	None	Yes	6–10	
51	67.50	67.50	67.50	10	Yes	Yes	12	
52	85	...	...	8	92.50	Yes	12	Yes
53	75	75	75	10	None	Partial	16	
54	62.50	75	75	8	Yes	Yes	12	
55	25–30	30–40	50[13]	10	None	Yes	12	
56	100	100	100	9	Yes	Yes	12	4–6
57	50	50	50	10	400	Yes	12–15	
58	150	150	150[14]	9	Yes	Yes	15–20	
59	85	85	85	10	Yes	Yes	12	
60	75	75	75	10	360	No[15]	12	
61	50	...	...	10	None	No	10	
	...	70	...	...	...	...	12	
	...	...	90	...	...	...	14	
62	75	75	...	10	400	Yes	20[16]	
63	50	50	...	10	120	...	12	
64	50	55	60	10	None[1]	No	10–12	
65	100	100	100	10	300	Yes	12	
66	100	100	100[17]	9	None	No	12	
67	87.50	87.50	87.50	10	Yes	Yes	9	3
Averages	77.77	81.13	87.65	9.7	...	...	13.5	...

[1] None charged. [2] After first year of service.

[3] Pay a reduced tuition rate of $2 per semester credit hour, about $40 per year. Fees are $1 per semester credit hours.

[4] Two ranks—Graduate Assistant and Assistant.

[5] Increase dependent on receipt of M.S.

[6] Total tuition charged to out-of-state students, no tuition for residents of state.

[7] For special cases, not necessarily because of second year of service.

[8] Permission to pay half-time tuition, thereby saving $190 per year.

[9] Fellowships at $83.33 per month for 12 months, plus remission of all tuition and fees, available for last year of doctoral work.

[10] Nine months of service. [11] With Bachelor's degree. [12] With Master's degree.

[13] "Hope soon to increase salary ... to $650 minimum."

[14] "It is hoped that these stipends may be increased ...."

[15] Student pays 10 to 20 per cent of cost of apparatus and supplies.

[16] Total net contact. [17] "We may raise assistantship salaries."

Statistical Methods in Research[1]

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METHODS and objectives of research have become extremely diverse in the last few years. Indeed, practically all of the standard techniques of physics and chemistry have been applied to this rapidly growing subject.

A statistical approach to the interpretation of experimental data, however, can be made quite generally without regard to the details of the experiment which furnished the data. For this reason, I propose to discuss the use of statistical methods from a rather general point of view rather than to attempt to describe their application to any specific problem in high polymers. Such applications will be apparent to any research worker. The illustrations which I will use are imaginary but bear definite resemblance to many real experimental results.

Physicists and chemists have been implicitly trained to a feeling of scorn toward statistical methods. It is generally felt that we only apply these methods when we have poor data and are too lazy to get good data. This is sheer narrow-mindedness. There are many instances where the brute force method of repeating an experiment in order to obtain greater accuracy is wasteful of research effort and is a sign of mental laziness, indicative of unwillingness to learn efficient methods of experimentation. In other cases it may be impossible to obtain data of the desired accuracy. But more important than either of these considerations is the fact that no set of data can be sucked dry of all legitimate conclusions without the use of statistics. It requires a statistical analysis to determine the best value for the atomic weight of silver, to determine whether certain experimental conditions can cause a shift in the wave length of a spectral line, to determine whether values of Planck's constant obtained by two different methods agree or disagree. Whenever conclusions depend on differences of the order of magnitude of the experimental uncertainty, statistical methods are required. It is only when we have drawn conclusions to this degree of fineness that we can be sure that we have obtained everything contained in the experimental data.

These remarks will strike many as truisms. I hope to justify this paper by describing certain methods which are not generally familiar to chemists and physicists. These methods, for the most part, have been developed by the English mathematician, R. A. Fisher, and his students. They were developed for the analysis of agricultural experiments, but possess such great generality that they are applicable to any kind of quantitative experimentation. Taken in their entirety, Fisher's methods constitute a subject much too large to cover in a single review. I shall limit the discussion to three topics—the test of significance, the factorial experiment, and single degrees of freedom. I shall not attempt to describe in detail how to use these methods, but rather what can be accomplished by their use. Details of technique are adequately covered in a number of textbooks.

The test of significance is basic to the statistical interpretation of experimental data. It is most easily understood by means of an example. In Table 1 are listed values for the tensile strength of two different rubber compounds.

TABLE 1

TENSILE (LB. PER SQ. IN.)

	Formula A	*Formula B*
	2900	3500
	3300	3700
	3100	3300
	3500	3600
	3200	3300
	3300	3500
Averages	3220	3480

I think that most experimenters would hesitate to draw any definite conclusion regarding the difference in tensile strength between compound A and compound B. Depending on the optimism of the research worker or perhaps on the state of his digestion, he might either conclude that his experiment had failed to show any difference between compounds A and B or that compound B was definitely superior to compound A. In the latter event he might fairly expect subsequent argument.

A statistical argument is necessary to resolve the dilemma. In the course of the argument, we shall apply what is called "a test of significance."

From the physical point of view the purpose of a test of significance is to answer the question, "Is there any real difference in tensile strength between compound A and compound B?" You are, of course, all familiar with the philosophical difficulties of the adjective "real." We shall therefore recast the question in order to avoid these difficulties and to allow use of a well-defined procedure. Instead, we ask, "What is the probability that there is *no* difference in tensile strength between these two compounds?" More precisely, we shall ask, "What is the probability that these data were drawn at random from a single normal population?"

We now arrive at material which is undoubtedly

[1] Presented at Brooklyn Polytechnic Institute on February 16, 1946.

familiar to many of you. It has been customary in physical research to express uncontrolled variation as an average deviation from the mean or as a probable error, then to assess the "reality" of a result in terms of these uncertainties. These procedures are logically unsound and mathematically inaccurate. It is preferable to proceed as follows: First, we obtain from the variation in each column of Table 1 from the average for that column an estimate of the standard deviation or spread of the normal population from which we assume the results to have been drawn. Next, we estimate the same standard deviation from the two averages. In each case we obtain an unbiased estimate of a single statistic. It can be shown, in addition, that this procedure makes the best possible use of the data at hand. We next compare the two estimates of standard deviation. If the estimates differ materially, we suspect the validity of our initial assumption to the effect that all of the data were drawn from a single normal population.

It is possible, however, to go quite a bit further than this. The sampling variation of the ratio of two estimates of standard deviation was discovered some years ago by R. A. Fisher. From the observed value of this ratio we can compute the probability that the two estimates of standard deviation came from a single population. In the present instance this probability is 0.05. This final step constitutes the test of significance. Our analysis leads to the conclusion that the chance of compound B's having shown the observed superiority over compound A fortuitously is only one in 20.

The procedure which I have outlined possesses the following advantages: first, it is entirely objective; second, it can be shown that no other analysis would give a conclusion of greater certainty; third, the conclusion is based on the results of this experiment and of this experiment alone. In most cases, this is a very real advantage since it automatically guards against fluctuations in testing error. There are other circumstances, however, in which a procedure of this type is unwise. The method can then be elaborated to include as much past experience as is desirable.

The method also possesses some disadvantages. First, there is the time consumed in making the analysis. This is not great. With the aid of a calculating machine, the small table which I have used for an illustration can be satisfactorily analyzed in about five minutes. More complex data would, of course, take proportionately greater time. Second, we consider the necessity for assuming a normal population to be a disadvantage. This disadvantage appears to be aesthetic rather than practical. The experienced experimenter will always know when the data depart materially from normality. An appropriate transformation can very nearly always be made to overcome the departure. Analysis has shown that the conclusions drawn from significance tests are not materially dependent on the shape of the parent population. Finally, I might cite as a disadvantage the fact that some people have a tendency to lean so heavily upon this tool that they lose sight of the physical meaning of their conclusions. The results of statistical analysis, like the results of all other kinds of analysis, must be tempered with common sense; otherwise, we can expect absurdity.

In the foregoing, I have dealt in some detail with a rather elementary example. The benefits of the statistical approach would be meager indeed if this were all that could be done. Actually, the test of significance is but the first tool to be drawn from a well-stocked chest. To illustrate this, we shall turn to the advantages obtainable from a more sophisticated experimental set-up.

We are frequently concerned with problems in which there are several independent variables. For example, in the study of copolymerization we must consider the catalyst, the emulsifier, the modifier, temperature, concentrations, etc. We have all been taught to approach situations of this kind by holding all variables constant except one and varying that one through a wide range. This is very elementary. It is more efficient in most cases to vary all variables simultaneously but in an ordered way, and is called a factorial experiment.

We can contrast the two methods of approach by recognizing that the dependent variable in a system of this type falls upon a surface in polydimensional space. Some of the dimensions in this space may be continuous (temperature, concentration), other dimensions may be discrete (nature of the catalyst or emulsifier). In any event, we wish to know the equation of this surface in as complete detail as possible.

Old-fashioned methods of experimentation yield data in which arbitrarily selected contours of the surface are mapped. An excessive amount of labor is required in order to cover the surface with any degree of thoroughness. We are reminded of an explorer traversing a beeline through a mountain range with his eyes glued to a compass; much interesting scenery may be missed. A factorial experiment, on the other hand, looks at the surface as a whole and in ordinary cases will reveal its distinguishing characteristics with much less work than would otherwise be required.

A factorial experiment is one in which each independent variable is assigned several values and all possible combinations of all assigned values of each independent variable are studied. Let us take a simple illustration. Suppose we wish to study the dependence of intrinsic viscosity of polystyrene on the nature of the catalyst and on temperature of polymerization. These two factors then become the independent variables of the experiment. For purposes of simplicity, let us assign two values to each. For the nature of the catalyst we shall select first, no catalyst, and second, benzoyl peroxide. For temperatures we may select, say, 80° and 100°C. We now have two independent variables with two values of each. The total number of combinations is therefore, four, and we obtain our results as follows:

TABLE 2
INTRINSIC VISCOSITIES

	Catalyst		
Temperature	*None*	*Bz_2O_2*	*Average*
80°	3.0	1.5	2.2
100°	2.3	1.1	1.7
Average	2.6	1.3	

So far we have learned nothing new, since many experimenters instinctively follow this pattern for experiments of this type. The novelty comes in the interpretation of the results. In order to determine the effect of the catalyst, we compare, not the individual results, but the averages over both temperatures—2.6 versus 1.3. Again, the effect of temperature is obtained by comparing 2.2 with 1.7. Each of these comparisons utilizes all of the experimental data. Because the experiment was symmetrically arranged in the first place, a symmetry appears in the interpretation. Thus, both temperatures are equally represented in the average for no catalyst and in the average for benzoyl peroxide. When we subtract these two averages, the first order effect of temperature, therefore, cancels out. The final comparison is obtained with materially greater accuracy than would be the case if we looked at our results one a time.

We have made two comparisons among four data. There is one more independent comparison which can be made. This corresponds to the so-called interaction between temperature and catalyst. This means the difference in response to the catalyst at high temperature ($1.1 - 2.3 = -1.2$) and the response at low temperature ($1.5 - 3.0 = -1.5$). This difference equals $-1.2 - (-1.5) = 0.3$ A little consideration shows that this interaction term expresses the mutual effect of catalyst and temperature as distinct from the first order effects of these two variables.

These three comparisons summarize efficiently all of the information contained in the original data. In this highly simplified set-up, however, there is insufficient information to carry out a test of significance. This can be obtained by repeating the experiment so as to obtain an error estimate and then proceeding along a path similar to that previously described.

The experiment just described was extremely simple. In actual practice we would normally use three to five independent variables and frequently more than two levels of each. For many types of laboratory work a single experiment involving 30 to 50 combinations is expedient.

The advantages of the factorial design are as follows: First, all of the data of the experiment bear on each question asked by the experimenter. This gives an accuracy which is truly surprising since we contrast the averages of 10 or 20 individual items for each of the comparisons of the experiment. This is a sizable improvement over looking at our results one at a time. Secondly, we are led to make a set of all possible independent comparisons among the data. There is an infinity of such sets, but the structure of the experiment specifies the particular set which we choose from this infinity. Because of this comprehensive treatment, we are sure that no observable effects will be missed in our study of the data. Third, we can ordinarily ignore higher order interaction terms and thus obtain a valid error estimate without any duplicate determinations. This means a tremendous saving in research time. Fourth, unless we cover all possible combinations of our independent variables, we risk missing an important interaction. This is frequently the case in the primitive method of varying only one variable at a time.

There are, of course, accompanying liabilities. The principal one is that if a unit of the experiment is lost, the value of the experiment as a whole is seriously impaired. This constitutes a limit on the useful size of factorial experiments. Secondly, it is ordinarily necessary to obtain all of the results of the experiment before any conclusion can be drawn. Very nearly always is it better to wait before a conclusion can be drawn with certainty than to give much weight to the early returns from the polls.

In describing the factorial experiment, I pointed out that we can make three independent comparisons from the four figures yielded by the simple two by two experiment. This statement is based on the fact that in this type of analysis we are always interested in discussing variations from the mean for the whole experiment. This means that upon receipt of the data, we first average all of the figures. If the experiment yielded n figures, there are $n - 1$ independent variations from the average. Each of these variations may be considered as a comparison among the original data, *e. g.*, the main effect of temperature in the two by two experiment discussed in detail. These $n - 1$ comparisons are called "degrees of freedom." The phrase is used in the phase rule sense. It is frequently desirable to design our experiments so that each degree of freedom has a worthwhile physical meaning. In an experiment of the most efficient type each degree of freedom will supply an answer to a specific question. The comparisons made in a factorial experiment constitute such a set of degrees of freedom.

The technique of using single degrees of freedom in analyzing experimental results gives us a means of looking at all results simultaneously rather than individually. Our conclusions thus have greater accuracy and generality.

Comparisons among experimental data can, of course, be made in many ways. Formally, we can represent a comparison by means of a set of numbers whose scalar product is to be formed with the experimental data, the product yielding a comparison. Such a set of numbers for the main effect of temperature in the data of Table 2 would be as follows:

$$\begin{matrix} -1 & -1 \\ +1 & +1 \end{matrix}$$

The over-all result of operating with these numbers on the data of Table 2 is -1.1. Similarly, the numbers necessary to give the effect of catalyst are:

$$\begin{matrix} -1 & +1 \\ -1 & +1 \end{matrix}$$

Finally, the interaction is given by:

$$\begin{matrix} +1 & -1 \\ -1 & +1 \end{matrix}$$

These three comparisons are mutually independent. It will be noticed that the sum of the numbers in any comparison equals 0. Further, the scalar product of

any one comparison with any other equals 0. These conditions are necessary for independence and, hence for maximum utility of this technique.

A further illustration for this technique is given by quantities which Fisher has termed "orthogonal polynomials." We have been used to thinking of least squares analyses as involving very laborious computations. This is generally the case, but there is one very important exception. If the independent variable is equally spaced so that by means of a linear transformation it can be represented by the ordinal numbers, 1, 2, 3 . . . n, the necessary computations are tremendously simplified.

Under these circumstances Fisher has developed a technique such that any set of values can be expressed as a power series of the form

$$z = f_0(x) + f_1(x) + f_2(x) + \ldots$$

where $f_n(x)$ is a polynomial of degree n in (x). The polynomials are so chosen that the first m terms in the equation constitute the least squares representation of the dependent variable in terms of a polynomial of degree m. In this analysis the independent variable is assumed to be known with complete accuracy, and each value of the dependent variable is given equal weight.

Many experiments yield a small number of points at equally spaced values of some independent variable. Let us assume the following data where x is the independent and z is the dependent variable.

x =	1	2	3	4	5
z =	3	7	6	9	12

Since we have five points, we can pass a curve of the fourth degree identically through every point. The arithmetic necessary to carry out this fitting is extremely simple. The multipliers for the single degrees of freedom are as follows:

Linear	−2	−1	0	+1	+2
Quadratic	+2	−1	−2	−1	+2
Cubic	−1	+2	0	−2	+1
Quartic	+1	−4	+6	−4	+1

This means that in order to obtain the linear term in the expansion, we form the expression:

$$-(2 \times 3) - (1 \times 7) + (0 \times 6) + (1 \times 9) + (2 \times 12) = 20$$

The over-all value of this contrast is 20. We determine the amount of variation associated with this term by squaring and dividing by the sum of squares of the multipliers in the linear degree of freedom (10). The total sum of squares of the data used in this illustration is 319. By means of the analysis which I have sketched above, this can be broken down into the following terms, each of which is associated with one degree of freedom.

Average	273.8
Linear term	40.0
Quadratic term	0.286
Cubic term	2.5
Quartic term	2.414
Total	319.0

It is apparent that the linear term is the only one of great importance. In actual practice we would probably neglect the quadratic and higher terms in any further discussion of the data.

The actual least squares equation is obtained in the following form:

$$z = 7.4 + 2(x-3) + \tfrac{1}{7}\left\{(x-3)^2 - 2\right\} + \tfrac{5}{12}\left\{(x-3)^3 - \tfrac{17}{5}(x-3)\right\} - \tfrac{13}{24}\left\{(x-3)^4 - \tfrac{31}{7}(x-3)^2 + \tfrac{72}{35}\right\}$$

Suppose we now consider a more complex case. Let us take a dependent variable, z, which is observed at five equally spaced values of an independent variable, x, and at three equally spaced values of an independent variable, y. The resulting 15 values are susceptible of 14 independent contrasts. Four of these are, respectively, the first, second, third, and fourth power terms in x, and two are the linear and quadratic terms in y. The remaining eight are interaction or cross-product terms of the form xy, xy^2, etc. For purposes of illustration, consider the following:

x =	1	2	3	4	5	Σx	*Linear*	*Quadratic*
y								
1	2	3	3	5	7	20	−1	+1
2	1	3	2	3	4	13	0	−2
3	0	1	1	1	1	4	+1	+1
Σy	3	7	6	9	12	37	$\bar{z} = 2.467$	

The multipliers used for the linear and quadratic terms in y are given in the last two columns above.

The terms associated with only one independent variable are obtained from the totals over the other independent variable. The multipliers for the interaction terms are constructed from the multipliers for the two single variable terms. For example, the multipliers for the cross-product term in xy are obtained from the linear multipliers for x and for y, yielding the following:

xy	+2	+1	0	−1	−2	20	−10
	0	0	0	0	0		
	−2	−1	0	+1	+2		

Similarly, the multipliers for xy^2 are as follows:

−2	−1	0	+1	+2	60	2
+4	+2	0	−2	−4		
−2	−1	0	+1	+2		

To the right of each table is given the sum of squares of the individual multipliers and the result of operating with the multipliers on the data of this illustration.

Proceeding in this way, we obtain an analysis of variance as follows:

	Sums of Squares
Average	91.2667
x	13.3333
x^2	0.0952
x^3	0.8333
x^4	0.8047
y	25.6000
y^2	0.1333
xy	5.0000
xy^2	0.0667
x^2y	1.2857
x^2y^2	0.0476
x^3y	0.0
x^3y^2	0.2667
x^4y	0.1143
x^4y^2	0.1524
Total	139.0

Here, we can lump the higher order interactions to obtain an error estimate, and with the use of this error estimate carry out the conventional test of significance.

This method is of such usefulness that when investigating problems of this type, it is highly desirable to carry out experiments at evenly spaced values of the independent variable so that use can be made of the appropriate orthogonal polynomials.

In conclusion, I must apologize for the sketchiness with which I have reviewed these topics. Unfortunately, the subject is one with which we must have experience in order to appreciate its versatility. For anyone interested in these methods, I suggest as references the following:

(1) FISHER, R. A., "Statistical Methods for Research Workers," Volume V, Oliver & Boyd, Edinburgh, 1938.
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(5) YATES, F., "The Design and Analysis of Factorial Experiments," The Imperial Bureau of Soil Science, Harpenden, England, 1937.
(6) FISHER, R. A., AND F. YATES, "Statistical Tables," Oliver & Boyd, Edinburgh, 1938.

Why Do We Believe in Electrons?

ANTHONY STANDEN

Interscience Encyclopedia, Brooklyn, New York

ANY discussion of the evidence for electrons in a chemistry or physics textbook begins with a description of J. J. Thomson's famous experiment of 1897 in which e/m, the ratio of the charge to the mass, was measured. Some chemistry textbooks state that this experiment "proves" that cathode rays consist of electrons; physics textbooks, naturally, give a more extended treatment, and they often quote J. J. Thomson's own words, which include the phrase " . . . I can see no escape from the conclusion that (the cathode rays) are charges of negative electricity carried by particles of matter." That the rays are charges of negative electricity is certainly inescapable, but careful examination of the experiment will show that it produces no evidence that they are carried by "particles" of anything at all.

If J. J. Thomson had discovered phenomena which could be more easily explained on the assumption of the electron than without, this would amount to the usual scientific basis for adopting a hypothesis. If the phenomena could be explained easily by the assumption of the electron but not at all or only with fantastic difficulty without this assumption, this would amount to as near as science ever gets to a "proof" of its hypotheses; our belief in atoms is, of course, of this nature. But although this experiment is compatible with the hypothesis that electricity is particulate, it is just as easily compatible with the hypothesis that electricity is not particulate but continuous.

The deflection of the rays by electrical and magnetic fields is, of course, no more easily explained with the electron than without. To explain the fact that the rays can pass through a thin sheet of aluminum foil, we need the atomic theory, which is attested by independent evidence, but we need make no assumption as to whether electricity is particulate or continuous. This is perhaps a little difficult to see because our habits of thought lead us to give no consideration to the possible behavior of nonparticulate fluids. But by way of an analogy, consider water thrown onto a layer of pebbles; it sinks to the bottom, penetrating through the interstices between the pebbles. No one would consider this as evidence of the particulate nature of water, and neither is the passage of the cathode rays through matter any evidence whatever for the particulate nature of electricity.

J. J. Thomson measured the ratio of the charge to the mass of the cathode rays. The measurement was made on the whole stream of rays, not on individual electrons in the manner of Millikan's oil drop experiment. The cathode rays were found to have an electric charge of 1.77×10^{-7} e. m. u. per gram of mass, or 5.65×10^{-8} grams of mass per e. m. u. of negative charge. Then, *on the assumption that the rays consist of uniform particles*, this measurement also holds for each individual particle. But the existence of the electron cannot be proved, or even indicated, by first assuming that it exists!

It is worth while to inquire into the historical circumstances that led J. J. Thomson to make his unjustified claim. At the time that he made the experiment, there were two theories about cathode rays: one was that they were electrons; the other, held by certain German scientists, was that they were some process in the ether of unknown nature. Having eliminated the German theory, which was more a confession of ignorance than an explanation, the British scientist plumped for the electron theory, which turned out, later, to be correct. Faraday's laws of electrolysis, together with the atomic theory, made the electronic theory decidedly plausible, but this plausibility was in no way increased by J. J. Thomson's experiment. The evidence for electrons was no stronger than before.

The purpose of this paper is not historical. It matters little whether the electron was discovered by this man or by that man, in 1897 or some other year. But it does matter, very seriously, that students are given bad reasoning in the guise of true.

The Objectives of Qualitative Analysis[1]

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WHEN a course becomes as firmly established as is qualitative analysis in the chemistry curriculum, it is easy to accept it as essential without thought or question. It would be well to make a critical appraisal of the objectives of this course to see whether the course actually does "put across" effectively the material considered to be most important.

Systematic qualitative analysis courses were introduced into the curricula of most universities before the turn of the century, and perhaps the only major advance has been the introduction of semimicro technique. With the increasing diversity in the activities of chemists a very small proportion of the chemists are ever called upon to make a systematic qualitative analysis after leaving college. Very few find any practical use for the procedures learned in qualitative analysis, and very few indeed remember more than a fraction of the systematic scheme employed in their college course.

Assuming, however, that an unusual fellow remembers enough of his "qual" to perform an analysis or that he keeps his college textbook handy, he can at best analyze for about 25 common metals out of over 90 elements, and perhaps a few common acid ions. Thus, since few ever perform a complete systematic analysis and since even if called upon to do so their analytical scheme would likely prove inadequate, we cannot defend the course as a practical one.

The best argument in favor of the course is that it teaches the fundamentals of chemical reactions in solutions. All too frequently the average student loses track of this worthy objective while he mechanically performs tests which he hopes will enable him to discover the ingredients of his "unknown." If we are seeking to teach the fundamentals of reactions in solution, ionization and equilibrium constants, solubility products and the like, laboratory experiments could and should be designed better to illustrate these.

To find out what chemists not in the teaching profession thought about qualitative analysis as a course, a brief questionnaire was sent to a number of the chemists in the vicinity of St. Louis. The results in Table 1 show that only 52 per cent of those replying thought that qualitative analysis should be retained in the curriculum. Approximately 60 per cent had never performed a qualitative analysis outside of college, and of this group which had performed an analysis, over 68 per cent had done less than 10 analyses.

Sixty per cent of those expressing an opinion felt that more emphasis should be placed upon fundamentals and less on the analytical scheme, while 35 per cent thought that at least some special methods of analysis could be substituted in place of the usual work.

If it is generally agreed that the fundamentals of reactions in solution, ionization and solubility product constants, and the like constitute the most important part of the qualitative analysis course as taught at present and that the analytical procedures in the laboratory are of secondary importance, does the present type of course attain the desired objectives? Although some qualitative analysis instructors who have expressed opinions on the subject felt that their students were aware of the beautiful interplay of solubility products and ionization constants as they precipitated the sulfides of the various metals, I feel that the average student is almost completely unmindful of such concepts as he struggles with unknowns.

To summarize, then, at its best qualitative analysis teaches students the general properties of the commoner metallic elements along with a few fundamentals of chemical reactions in solutions. Its advocates also claim some benefits derived from the experience in the "scientific method of approach." At its worst, it encourages careless working. The very nature of the analysis of "unknowns" is apt to lay more stress on the detection of a number of ingredients in a mixture cunningly compounded for the purpose than on the understanding of the principles involved. With the introduction of specific organic reagents and refined instrumental methods of analysis the whole framework of the old systematic qualitative analysis is becoming archaic, and its only justification is its value in teaching general principles. The implication is made that the usual type of laboratory work fails to attain the most desired objective of the course, and it is hoped that thought may be stimulated which will result in the development of a more useful and more effective course.

TABLE 1

RESULTS OF SURVEY OF CHEMISTS' OPINIONS ON QUALITATIVE ANALYSIS COURSE

58%	of those answering had performed *no* qualitative analysis outside of college
68%	of those who had done any analyses had done less than 10
52%	of those answering thought qualitative analysis should be retained in curriculum
60%	of those expressing an opinion suggested more emphasis on fundamentals
35%	of those expressing an opinion suggested some work in special methods

QUESTIONNAIRE SENT TO 135 CHEMISTS IN THE ST. LOUIS AREA

Outside of college courses, I have performed about_____(1, 10, ?) complete systematic qualitative analyses.

The usual systematic qualitative analysis course should be retained in the college curriculum. Yes__ No__ Undecided—

The time consumed in qualitative analysis could be utilized to better advantage in

( ) more emphasis on fundamentals of chemistry
( ) work in special methods of analysis
( ) other suggestions_____

[1] Presented before the Division of Chemical Education at the 109th meeting of the American Chemical Society in Atlantic City, April 8–12, 1946.

Report of the
NEW ENGLAND ASSOCIATION
of CHEMISTRY TEACHERS

A Survey of Synthetic Medicinals[1]

C. PAULINE BURT

Smith College, Northampton, Massachusetts

EARLY in the 17th century there appeared a remarkably prophetic book by a great English author, "The New Atlantis" by Sir Francis Bacon. In it the author told a fabulous story of discovering an unknown island where civilization had been developed to a remarkable degree and where a kind of Rockefeller Foundation had been set up for the purpose of "interpreting nature and producing great and marvelous works for the benefit of man." This institution, called Salomon's House, was a great school of research subsidized by the commonwealth and founded upon the principle that only organized group action can bring far-reaching scientific results. One department of this college was devoted to herbs, drugs, and other ingredients of medicine, and here the scientists of Salomon's House were engaged not only in what Bacon calls the "exquisite distillation" of natural herbs and plants, but also in isolating the effective chemical constituents of natural compounds and even making such constituents synthetically. Bacon does not go on to say that by means of isolation and synthesis his chemists were able to *improve* on nature; he says, with great admiration, that they nearly *equal* her. In other words, his scientists fell short of the point to which 20th-century science has progressed. But in certain respects he has given in this description an extraordinary prophecy of the work of the organic chemist in providing agents for chemotherapy and for the relief of pain and suffering.

The distinction which Bacon draws between natural and synthetic medicines is of paramount importance. The underlying principle of chemotherapy is that certain chemical compounds have a special affinity for certain substances; they must do their job on the specific substances alone without wreaking havoc on perfectly healthy living cells in the body.

The chemist's investigation of the precise structure of a natural medicinal consists first of all in discovering the active principle of the raw material to which its power is due. Take as a simple illustration a natural medicinal of long and distinguished history, *mandragora*. The shape of this plant, with its long, forked roots, bears some resemblance to the human form, and according to an old legend, it was supposed to utter unholy cries when it was torn from the earth. As early as the first century, however, man apparently got the better of his superstitions and began to apply it locally for the relief of pain. Some centuries later it found another medicinal application in a brew which was used as a hypnotic. "Look where he comes," says Iago of the jealous Othello,

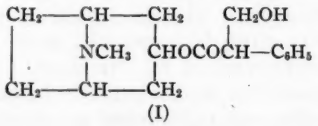
> Not poppy nor mandragora
> Nor all the drowsy syrups of this world
> Shall medicine to thee that sweet sleep
> Which thou owdst yesterday.

And when Cleopatra was deserted by her lover, she attributed to this extract hypnotic powers of extraordinary duration:

> Give me to drink mandragora
> That I may sleep out this great gap of time
> My Antony is away.

Yet the whole mandrake plant is not efficacious medicinally; we now know that its active principle is atropine (I). It is used primarily to dilate the pupils of the eye and, when given preoperatively, to stimulate respiration—a considerably more limited function than that which it once enjoyed as an analgesic and hypnotic. It still plays something of its erstwhile part, however, as a component of ointment of belladonna.

Atropine, constituent of the roots of the belladonna plant



(I)

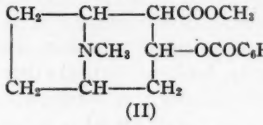
This is a case where the chemist has simply isolated the single one of many organic compounds in the plant structure. In other cases this active principle is not sufficiently selective in its behavior; it acts upon other cells as well as upon those for which it is a corrective agent. Here the chemist is asked to break down the molecule and, by rearranging or by making substitutions in the component parts, to build up a new but related substance which will really do the trick. Cocaine (II), the active principle in the coca leaf, has important anesthetic properties but is highly toxic and habit-forming; novocaine, which, chemically, is cocaine shorn of some of its excrescences and adornments, has better anesthetic properties and is much less toxic and

[1] Delivered at the Sixth Summer Conference of the N.E.A.C.T. Connecticut College, August, 1944.

habit-forming. But novocaine, synthesized early in this century, was only the first of a number of synthetic local anesthetics which have found their way into use.

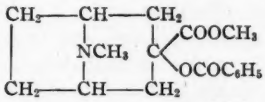
Two things were soon observed about these organic chemicals: first, that *slight* modifications in the molecule often gave substances of no activity whatsoever (compare II and III), and second, that other modifications of structure gave anesthetics of differing specific powers. Research then led in the direction of systematically changing an active molecule, testing each active product for a particular use. This is, as you know, the systematic approach to synthetic medicinals which is being used in all parts of the globe. In the case of local anesthetics, almost all are made in the "image of cocaine," but a physician selects the one he wants for his purpose. Some are better for eye operations, others for nose or throat, some for injection anesthesia, still others for spinal anesthesia. Formulas IV through VII show a few of the usable substances and their variations in structure. Thus, Bacon's prophecy of synthesizing medicinals equal to those in nature was quickly surpassed once the chemists got to work. While many new compounds have had as their take-off point a natural product, the work today is in the direction of man-conceived molecules which have no counterpart in nature.

Cocaine, constituent of the leaves of the coca plant



(II)

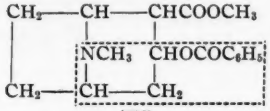
α-Cocaine (synthetic), isomeric with cocaine



Not an anesthetic

(III)

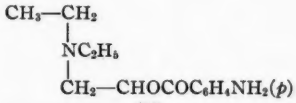
Cocaine (anesthesiaphore group encircled)



(IV)

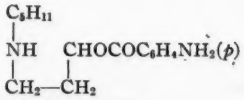
SYNTHETIC LOCAL ANESTHETICS WITH ANESTHESIAPHORE GROUP, SIMILAR TO THAT OF COCAINE.

Procaine or novocaine



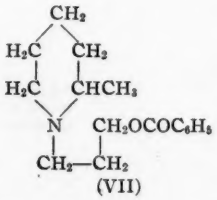
(V)

Amylcaine



(VI)

Metycaine

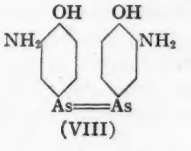


(VII)

But lest I get ahead of my story in dealing first with local anesthetics, I hasten to tell you that the systematic approach of which I have been speaking was first employed extensively by Paul Ehrlich in his classic work on arsenicals when he was searching for a little-toxic compound which would rid the world of one of its greatest scourges. Starting, as you know, with the fact that arsenic, a violent poison, had a deleterious effect on syphilitic organisms, he set about synthesizing a compound which would be little-toxic enough to admit of practical application, and not until the 606th compound had been tested was he satisfied that he had produced the usable one which he called "606" (salvarsan), chemically known as arsphenamime.

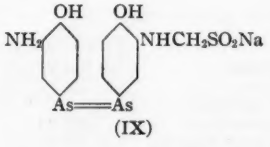
Although time has shown that salvarsan, while not ideal, was as effective as Ehrlich thought, its use has by no means stamped out syphilis in the civilized world. Even Ehrlich himself was not content to say, "Here is an effective substance—it cannot be improved." As a matter of fact he soon saw that its toxicity, lack of solubility, difficulty of administration, and the necessity of varying the treatment because the organisms established a tolerance against it, were sufficient reasons one and all of them for continuing his search for a

ARSENICALS OF THE TRIVALENT TYPE



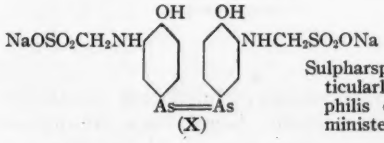
(VIII)

Salvarsan, arsphenamine, "606," effective in syphilis, most efficient one in this group, and administered as salt intravenously



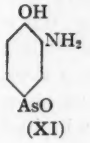
(IX)

Neoarsphenamine, "914," effective in syphilis and administered intravenously



(X)

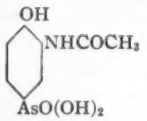
Sulpharsphenamine, used particularly in congenital syphilis of infants and administered intramuscularly



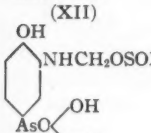
(XI)

Mapharsen, used particularly in early syphilis

ARSENICALS OF THE PENTAVALENT TYPE

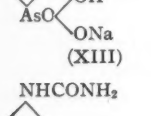


(XII) Acetarsone, used in amebiasis



(XIII) Aldarsone, used for central nervous system syphilis

(XIV) Carbarsone, used for intestinal amebiasis



(XV) Tryparsamide, used for central nervous system syphilis

better substance. He went on to produce "914," and since then the work has continued with the same general results as when the novocaine molecule was modified. The new substances show new specificities. Marpharsen is used for early syphilis, tryparsamide for late syphilis, sulfarsphenamine for children. These substances, all of the same general image, are still used today. (See VIII–XV.)

But to go back to specificity of action and anesthetic effects, while cocaine and its modifications give local anesthetic effects, other compounds, truly synthetic, may be used as general inhalation anesthetics. Practically all of these—ether, divinyl ether, chlorethene, ethylene, cyclopropane, etc.—are well known to you, and yet I want to show you their structures (XVI through XX) in order to emphasize that they are all

GENERAL INHALATION ANESTHETICS

		Boiling point, °C.
$CH_2{=}CH_2$ (XVI)	Ethylene	−103.9
$C_2H_5{-}O{-}C_2H_5$ (XVII)	Ether	34.5
$CH_2{=}CH{-}O{-}CH{=}CH_2$ (XVIII)	Divinyl ether (vinethene)	28–31
$CCl_2{=}CHCl$ (XIX)	Trichloroethylene	88.0
$CH_2{-}CH_2$ (XX)	Cyclopropane	−34.4

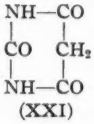
somewhat similar chemically. Inhalation anesthetics must, of course, be volatile; hence, these are organic compounds with few carbon atoms. The mother substance is ethylene, a gaseous substance which has much to be said for its use since it is rapid in action, causes little or no post-operative nausea, and induces a sleep which is tranquil and more nearly like normal sleep than can usually be obtained. Its use has been limited since it is explosive and thus somewhat hazardous to administer and control. Ether, the good old standby of inhalation anesthetics, is a derivative of ethylene; in fact it is prepared from ethylene in two simple steps. It was known as a chemical entity as early as the 13th century, but its property of producing insensitivity to pain was not recognized for five and one-half centuries.

Divinyl ether, patented in 1935, is a short-duration anesthetic and is therefore used in minor surgical operations or in obstetrical procedure. It is very rapid in action; in the treatment of a broken arm, for example, a small vial can be broken (divinyl ether boils at about 30°), the patient takes a few whiffs, and the bone can be set immediately. Only about 5 per cent of the cases show any post-operative nausea. Trichloroethylene has also demonstrated its effectiveness for a particular purpose. The pains of angina pectoris and trigeminal neuralgia are quickly relieved by brief inhalation of this substance. Thus again we see that the chemist's modifications of an active compound tend toward specific substances for specific uses.

Although a chemist understands the difference between general and local anesthetics, it is not always clear to him whether they can be used as alternatives. The main tendency up to the last ten years has been to use general anesthetics for surgical cases; the doctors

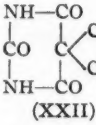
BARBITURATES

Barbituric acid (*Malonyl urea*)



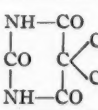
(XXI) ← the 5,5-position. Compound not a hypnotic

Barbital (*Veronal*)



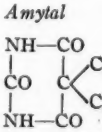
(XXII) ← 5,5-diethylbarbituric acid. Good hypnotic, introduced in 1903

Phenobarbital



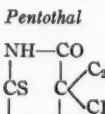
(XXIII) Good hypnotic, long duration

Amytal



(XXIV) Good hypnotic, moderate duration

Pentothal



(XXV) Used as sodium salt, administered intravenously for an anesthetic

trained and interested in the techniques of injecting local anesthetics were in the minority. But some of the equipment for administering general anesthetics proved to be too elaborate and too heavy to be used at the front lines in the war; general anesthetics are mostly explosive and are therefore dangerous at the front and on naval vessels. Furthermore, the effects of post-operative nausea and shock are particularly undesirable for war casualties; hence, there has been a renewed interest in local anesthetics and the techniques of their administration. The Russians have developed a slow infiltration method of giving local anesthetics which has proved highly successful. The United States prefers intravenous or spinal anesthesia, two other techniques which bring equally good results.

While anesthetics produce insensibility, they cannot in general be said to produce sleep, and any of you who have passed sleepless nights have turned not to anesthetics but to hypnotics and sedatives. Chloral hydrate, paraldehyde, and bromides were all well known before the 20th century, but they have decided limitations in use. The fairly safe and enduring hypnotics came early in this century as truly synthetic compounds which had no counterpart among natural products. I refer, of course, to the barbiturates. Veronal (or barbital) was patented in 1903, marking a new era in hypnotics. It can be taken by mouth, is non-habit forming, fairly free from harmful effects, quick in action, sufficiently soluble, and lacking in disagreeable taste. From 1903 to today hundreds of barbiturates have been synthesized, and 10 to 20 are in common use. Formulas XXI through XXV show the structure of barbituric acid and some of its substituents, of which the diethyl derivative is barbital (or veronal). Note that most of these compounds vary only in the substituents in the 5,5-position.

The variation in these groups produces differences in duration, intensity, speed of effectiveness, solubility, and toxicity. The intensity of the action varies with different barbiturates from slight sedation to an anesthetic state; the duration from minutes to eight or ten hours; the speed of effectiveness from a few minutes to an hour or so. Thus a physician is able to select the compound he wishes, whether it is to induce slight sedation before the patient is taken to an operating room, or deep sleep for a few hours or for overnight. Lest I leave you with the idea that these are perfect substances, I hasten to add that they are by no means altogether non-toxic or perfect in action. If taken over a period of time, they may produce a tendency to rely upon them which is in a way habit-forming. The perfect hypnotic does not exist and probably never will, but we will continue to look for it and approach it.

(*To be continued*)

NEW MEMBERS

Sister M. Claire, S.S.J., Regis College, Weston 93, Massachusetts

Rev. Leo J. Daily, St. Thomas' Seminary, Bloomfield, Connecticut

Sister Marie St. Blaise, Presentation of Mary Academy, Hudson, New Hampshire

Robert W. Card, Winchester High School, Winchester, Massachusetts

H. Howard Lynch, Technical High School, Springfield, Massachusetts

LET'S GET TOGETHER

FOR THE REAL FIGHT

Courtesy *Appreciate America, Inc.*

RECENT BOOKS

ATOMIC AND FREE RADICAL REACTIONS. The Kinetics of Gas-Phase Reactions Involving Atoms and Organic Radicals. *E. W. R. Steacie*, National Research Laboratories, Ottawa. Reinhold Publishing Corporation, New York, 1946. viii + 552 pp. 26 figs. 54 tables. 15 × 23.5 cm. $8.00.

This new addition to the American Chemical Society Monograph Series fills a distinct need in the literature of chemical reaction kinetics and photochemistry. The author has assembled information regarding a large number of reactions involving atoms and free radicals, and has given a critical evaluation of the data wherever they are sufficiently extensive. In view of the unusually large number of apparently different interpretations and opinions prevalent in the field of reaction kinetics, this critical treatment is both valuable and stimulating. The arrangement and discussion of the material should stimulate particularly further research on some of these interesting reactions.

Types of elementary reactions, the role of atoms and radicals in chemical kinetics, and a few fundamental ideas of reaction kinetics are discussed in a brief introduction (Chapter I). This is followed by a very complete chapter on the experimental methods used in the production and study of atoms and radicals.

The next three chapters (III, IV, V) present in some detail the atomic and free radical mechanisms of the most thoroughly investigated thermal and photochemical reactions. A number of controversial topics are critically discussed here. Of particular interest are the following: "bond-strengths"; activation energies of elementary reactions; mechanisms of decompositions of hydrocarbons, ethers, aldehydes, ketones, and azo compounds; thermal and photochemical polymerization reactions; photochemical reactions of aldehydes, ketones, and halogen compounds.

The remaining nine chapters contain data pertinent to the kinetics of the principal elementary reactions. The data are arranged systematically according to the individual reactions, which are classified by the elements which they contain. The data on systems containing carbon and hydrogen only are most extensive. Systems containing oxygen, the halogens, nitrogen, sulfur, sodium, and other metals are discussed separately in the following chapters.

This monograph is strongly recommended to workers in the field of reaction kinetics and photochemistry as a valuable reference work in these subjects.

A. B. F. DUNCAN

UNIVERSITY OF ROCHESTER
ROCHESTER, NEW YORK

PHYSICAL CHEMISTRY FOR PREMEDICAL STUDENTS. *John Page Amsden*, Professor of Chemistry, Dartmouth College. McGraw-Hill Book Company, Inc., New York, 1946. ix + 298 pp. 54 figs. 39 tables. 13 × 21 cm. $3.50.

This book is designed for a one-semester course. Although the treatment of the subject is conventional, the book is thoroughly up to date. Descriptions of a number of effective lecture demonstrations are included, and many of the principles discussed are illustrated by examples which are of particular interest to premedical students.

The book is attractively set up and very well printed. There are almost no misprints and with one or two exceptions the subscripts and superscripts, which must be a typesetter's nightmare, are well placed.

The chapter headings are: I. Dimensions and Units; II. Gases; III. Liquids; IV. Solutions; V. Properties of Solutions, Solutions of Nonelectrolytes; VI. Properties of Solutions, Solutions of Electrolytes; VII. Chemical Equilibrium; VIII. Hydronium Ion; IX. Oxidation and Reduction; X. Speed of Reaction. Catalysis. Adsorption; XI. The Colloidal State. The Donnan Equilibrium.

The first two chapters are good. In Chapter III considerable space is devoted to a discussion of surface tension and viscosity. It seems unfortunate, in a book like this, in which many important subjects must be seriously compressed or omitted altogether for want of space, to employ so many pages in covering material which the student should already have studied in physics. Perhaps it is time for teachers of physics and physical chemistry to get together and eliminate some of the duplication which exists between these subjects.

The three chapters on solutions are excellent. The choice of concentration units for expressing the solubility of gases, given in Chapter IV, is open to some criticism, since weight per unit volume and weight per unit weight (other than mol fraction) are omitted, and the less useful Bunsen absorption coefficient is included. The chapter on the properties of electrolytes is especially good.

Although Chapter VII is entitled "Chemical Equilibrium," almost all of it is confined to equilibria (the author uses "equilibriums") in aqueous solution. Here also the approach is modern, but there is a little back-sliding in the discussion of hydrolysis. For example, the explanation of the hydrolysis of potassium cyanide includes this (p. 158): "If potassium cyanide, which is a salt of the weak acid hydrocyanic acid, is placed in water. . . ." On p. 163 the author attempts to give this in more up-to-date language, but he speaks of the reaction as an "ionization." The reviewer feels that a single presentation of the subject in terms of protolysis reactions, for which the groundwork has been adequately laid, would be preferable.

The chapter on "Hydronium Ion" is on the whole very well done. Especially commendable is the brief discussion (pp. 181–2) of the conversion of mols per liter into pH; unfortunately the reverse calculation (pp. 182–3) is not carried out with the same insight into student difficulties. The reviewer can see no reason, although this admittedly is a matter of opinion, for using the name "hydronium ion"; "hydrogen ion" is adequate, if it is carefully defined as a proton attached to a molecule of solvent. Also pK_w seems preferable to pW, especially since the author continues to use the usual pK_a.

Chapter IX, which deals with oxidation-reduction reactions from the point of view of electrochemistry, is brief and concentrated, but effective.

Chapter X, entitled "Speed of Reaction. Catalysis. Adsorption," is, in the reviewer's opinion, the least satisfactory chapter in the book. This may well be inherent in the nature of the subject matter and not altogether the fault of the author. On reading this chapter, one receives the impression that a great deal of subject matter is being crowded into far too little space. Reaction velocity is presented in eight pages; in this brief space adequate discussion is impossible. The terms "order" of reaction and "molecularity" are used as if they are synonymous. Energy of activation is not introduced at all; as a consequence the discussion of catalysis is primarily empirical. Catalysis receives only four pages, and adsorption seven more.

In the final chapter, entitled "The Colloidal State. The Donnan Equilibrium," the treatment again suffers from too much compression. Fourteen pages are devoted to the colloidal state before the discussion of the Donnan equilibrium begins. It seems to be conventional to include the Donnan equilibrium in courses in premedical physical chemistry, but the question may well be raised whether the time so spent might not more profitably be spent on some less specialized subject. Discussion of the Donnan equilibrium is to a large degree anticipation of work which must be done in the medical schools.

In spite of the general excellence of the book there are a number of misleading statements and a few downright errors. Attention should be called to some of these. For example, on p. 34, the author apparently forgets the existence of the Clausius-Clapeyron equation when he says: "There is no general rule relating temperature to vapor pressure, although several empirical equations

have been proposed. . . ." The values of the ionization constant for acetic acid (Table 22, p. 150) increase as the concentration decreases; the discussion on p. 157 would properly lead one to expect the opposite effect. The author is sometimes careless of precision; for instance, in Example 2, p. 175, the concentration of silver chromate is given as 8×10^{-5} molar, but from this the K_{sp} for silver chromate is calculated to four significant figures: 2.048×10^{-12}. Standard electrode potentials are given (p. 189) in terms of molarity rather than the accepted molality. On p. 199, the statement is made that "Hydroquinone is not so easily oxidized as is hydrogen gas." What is meant, of course, is not hydrogen gas as such but hydrogen adsorbed on platinum black. In several places, the author uses "is proportional to" where "increases with" or "depends upon" would be correct; for example, on p. 257, this passage occurs: "The amount of solute adsorbed per unit weight of adsorbent is proportional to the concentration of the solute. . . ." This is incorrect, since the amount adsorbed is not a linear function of the concentration. Exception might be taken to the statement (p. 268), "Colloidal particles have no motion of their own, but the impacts of the molecules of the dispersion medium on the particles of the dispersed phase may produce an erratic zigzag motion in the latter." From this point of view, no single molecule could be considered as having any "motion of its own."

In his preface the author says: "Since physical chemistry is valuable only as it can be used to solve problems in practice and in research, it is necessary that the student gain as much practice as time permits in the application of principles to the solution of problems." Certainly practice in working problems is valuable, and a large number of well-selected problems are included, but the statement that the *only* value of physical chemistry comes from problems cannot go unchallenged. Physical chemistry is not a subject which is devoid of ideas, nor is it devoid of value as an intellectual discipline, nor for that matter is it devoid of cultural value. Fortunately, the book gives little evidence that the author really believes what he says here. In spite of the criticisms given, the reviewer feels that this is an excellent book, which is sure to be adopted widely and used successfully.

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MODERN PLASTICS, *Harry Barron*, Head of Plastics Department, Pirelli General Cable Works, Ltd., Adviser on Plastics, General Electric Company, Ltd., and Lecturer on Plastics, University College, Southampton. John Wiley & Sons, Inc., New York, 1945. xvi + 680 pp. 250 figs. 166 tables. 14 × 21 cm. $7.50.

The author frankly states, "This book is an effort to provide an adequate technical background" on plastics, and "any reader with a modest scientific or engineering knowledge will be able to obtain an over-all view of the industry." He has "not written the book for the experts." He has "omitted certain common materials such as shellac, bitumens, rubber plastics, etc." and has "not given any consideration to materials such as allyl resins, silicon resins, boron resins, although" he is "fully aware of their existence."

In organizing the subject matter, he has "adopted the scheme based on association of ideas. Moulding is associated with phenolic resins, injection moulding with cellulose acetate, extrusion with polyvinyl chloride, fibres with nylon, safety glass with polyvinyl butyral, and that is where you will find them."

The author wrote the book in Southampton "on the eve of the Allied invasion of Europe" and from his window he saw "the massive panoply of war, weapons, materials, etc., incorporating vast quantities of plastics in every shape and form, pass on the way to action." He looks "forward to the corresponding applications in more peaceful activities."

He has used the subject matter incorporated in the book in his university lectures and is "encouraged to believe that a much wider circle may benefit from them." In this thought the reviewer believes he is right.

In these 680 pages he has gathered together a large amount of good up-to-date information in readable form to fulfill his purpose. The book covers the chemistry and physics of plastics, the materials of which plastics are made, and the methods of manufacturing both chemicals and plastics. He gives brief historical backgrounds where they are of interest. His theoretical discussions are good and adequate for a book of this type. There is an abundance of tables, graphs, charts, and diagrams. The book is full of well-chosen photographs, but they suffer from poor printing. In fact, the entire presswork of the book shows the effect of war conditions.

The use of trade names along with the chemical names of plastics is commendable. So also is the discussion of methods of analysis and of physical testing.

Each chapter is supplied with a list of references. The book has a very good name and subject index.

Although the author is English he has made excellent use of foreign literature. He openly criticizes his own country for its lack of work and of production in this field. His "own desire is to see Britain leading in these activities and not trailing behind." An interesting English flavor is found in some of the statements and in some spellings—colour, jewellery, plasticiser, etc. He states, "It should be well understood, therefore, that the preparation of plastics is essentially a chemical industry" (p. 33). Also, "The Americans have an innate craving for gadgets" (p. 16). In the discussion of injection molding he tells how it was invented for molding the unstable cellulose nitrate and could only be used when a stable plastic like cellulose acetate came on the scene, and comments, "This is an outstanding example of a technique waiting for a suitable material" (p. 341). The work on casein plastics was started in a competition in Germany in 1897 for making *white* blackboards because they "apparently were considered to have superior optical characteristics" (p. 570).

The reviewer was introduced to an intriguing and to him new word, "hydulignum," the name of a British compressed laminated wood employed for propellers (p. 529).

The author gives his work a beautiful dedication.

HARRY L. FISHER

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SURFACE ACTIVE AGENTS. *C. B. F. Young*, Director of Research, Clark Babbitt Industries, Inc.; Adjunct Professor, Brooklyn Polytechnic Institute; Head, Institute of Electrochemistry and Metallurgy; and *K. W. Coons*, Professor of Chemical Engineering, University of Alabama; Technical Director, National Southern Products Corporation. Chemical Publishing Company, Inc., Brooklyn, 1945. x + 381 pp. 41 figs. 14 × 22 cm. $6.00.

Good books in new fields of knowledge do not suddenly spring to perfection, but frequently arise through the successive efforts of different workers to clarify and summarize the relatively disconnected and poorly understood facts. This book, through being a pioneer in the field, has suffered from lack of precursors to serve as models or to be improved upon. It is, however, a commendable product of much effort by the authors to furnish a useful compendium of information on surface-active agents.

Part One opens with two chapters on the "Theory of Surface Tension" and the "Determination of Surface Tension." Chapter 1 is a fair introduction to surface tension with a minimum of theory. The second chapter seems to devote too much time to details of little interest except to the investigator in this field who should turn to the physical chemical literature.

The last chapter of Part One, however, compensates for the other two. It is a praiseworthy assembly of information on the chemistry of surface-active compounds, with an extensive list of commercial products. It is to be hoped that future lists can be more specific on chemical composition and uses. The reviewer ventures to suggest that competitors usually know many details of the other fellow's products that have not found their way into the general literature.

Part Two contains twelve chapters on as many different fields

in which surface activity is prominent. The treatment in some cases is too general to be of great value, and it is suggested that more service would have been rendered to the inquiring public had the authors reduced the space given to general descriptions of broad fields of technology and concentrated more on the surface problems. Nevertheless, there is much information contained in these two hundred pages. The student seeking a purview should find this book useful, and there are many practical suggestions for those "skilled in the art."

The numerous and well-chosen references at the ends of the chapters contribute materially to the value of the book.

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THE AMINO ACID COMPOSITION OF PROTEINS AND FOODS. *Richard J. Block*, New York Medical College, Research Director, C. M. Armstrong, Inc., New York, and *Diana Bolling*. Charles C. Thomas, Springfield, Illinois, 1945. xiv + 396 pp. 169 tables. 4 figs. 17 × 26 cm. $6.50.

Methods for the determination of the 21 commonly accepted amino acids and six other amino acids (citrulline, dihydroxyphenylanaline, homocystine, homocysteine, hydroxylysine, and ornithine) in proteins and foods are described in the first eight chapters (285 pages) of this book. Detailed experimental directions are given for the determination of these amino acids by gravimetric, colorimetric, gasometric, enzymatic, iodometric, polarographic, and selective oxidation methods. Alternative methods for the determination of each amino acid are presented and the principle, the historical development, the reagents, the experimental procedure, and the shortcomings of each method are discussed.

The sources of proteins and foods analyzed, the analytical procedures employed, the names of and references to authors who made the analyses, the percentages of total nitrogen in the proteins and foods, and the percentages of particular amino acids in animal (albuminoids, blood proteins, egg proteins, milk proteins, tissue proteins, organs, glands, hormones, enzymes, and keratins) and plant (corn proteins, seed globulins, seed proteins, grasses, leaves, viruses, yeasts, yellow enzymes, wheat proteins, and wheat products) materials are tabulated at the end of each chapter. The averages of the individual amino acid values are given in 14 summary tables in Chapter X. The 699 references to the literature are arranged both numerically and alphabetically.

Ten pages (Chapter IX, Part II) are devoted to a discussion of the general principles of Fischer's fractional distillation of amino acid esters, Engeland's exhaustive methylation of amino acids, Neuberg and Kerb's precipitation of amino acids as the mercury carbamates, Ruhemann's oxidation of amino acids with ninhydrin, Dakin's extraction of monoamino monocarboxylic acids with butanol, Ehrlich and Brazier's fractionation of amino acid copper salts, Kingston and Schryver's precipitation of amino acids as barium carbamates, Boyd's fractionation of carbamido acids, Przylecki and Kasprzyk's separation of amino acids by means of dry fatty acids, Bergmann and coworkers' determination of amino acids by the solubility product of their salts, Rittenberg and Foster's isotope dilution method, Tiselius and others' separation of amino acids by chromatographic adsorption, and Lyman and coworkers' microbiological determination of amino acids.

Tests for the determination of glucose, fructose, galactose, mannose, and hexosamine are described on pages 297 and 298 (Chapter IX, Part III). On pages 307 to 309 (Chapter XI) the essential amino acid requirements of man are discussed, and three tables of data are given showing the estimated average annual *per capita* consumption of essential amino acids in the United States 1937–41, the daily essential amino acid requirements, and the percentage of optimal daily requirements of each of the essential amino acids supplied by 100 grams of protein from meat, milk, white flour, vitamin-enriched bread, corn, and soybeans. Daily allowances of essential amino acids considerably smaller than those suggested by Block and Bolling have been proposed recently by Stare, *et al.*,[1] and it seems probable that the requirements will be found to vary widely with the species of animal as well as with the sex, age, and physiological condition of the individual. There are nine pages of author index and 37 pages of subject index.

The problem of protein hydrolysis is adequately discussed in the Introduction and in Chapter IX, Part I. It is emphasized that the susceptibility of each and every amino acid to loss during hydrolysis is different and differs not only with the conditions of hydrolysis but more so with the presence or absence of other substances in the hydrolysis mixture. It is pointed out that attempts to evaluate hydrolytic losses by adding the amino acid under investigation both before and after hydrolysis require the tacit assumption that the amino acid added to the protein reacts during hydrolysis in exactly the same way as its analog in the peptide linkage. Special consideration is given in almost every chapter to conditions recommended for the hydrolysis of proteins and to empirical factors for the correction of amino acids destroyed during hydrolysis and lost during analysis. It appears, however, that some of the recommendations have been made without substantial evidence as to their validity.

All of the amino acid data in the tables are calculated on the basis of 16.0 per cent nitrogen "in the interest of uniformity and to facilitate comparison." Vickery and Clarke[2] have raised objections to this practice, but no basis of calculation more satisfactory for foods and most proteins was proposed. It may be pointed out that some of the amino acid values reported previously may be inaccurate because of errors resulting from unreliable data for ash and total nitrogen.

"Best values," representing the authors' personal opinions, and the mean values calculated with twice the standard error are presented in the tables. It appears, however, that many of these data are not highly reliable and that, for the most part, neither the analytical procedures nor the amino acid data have been evaluated critically. Though highly desirable, this would have been difficult since not all of the methods described in the authors' book yield amino acid values of acceptable quantitative accuracy. It is mentioned (page 292), but not emphasized sufficiently, that amino acids in protein hydrolyzates may be determined with high accuracy by the isotope dilution procedure. While it was not possible for the authors to give an adequate account of the microbiological methods which have been applied during the past two years to the determination of many amino acids in numerous proteins and foods, it seems certain from the available evidence that some amino acids may be determined with greater convenience and accuracy by microbiological procedures than by almost any of the classical chemical methods.

This book is well bound and excellently printed, it is unusually free from typographical errors, and it is a nearly complete record of amino acid methods and data published prior to 1944. It may be recommended, particularly, as a ready source of information on analytical procedures for the determination of amino acids, on the relative lability of amino acids *per se* and in proteins, and on the amino acid data given in the literature.

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[1] STARE, F. J., D. M. HEGSTED, AND J. M. MCKIBBIN, *Ann. Rev. Biochem.*, **14**, 431 (1945).

[2] VICKERY, H. B., AND H. CLARKE, *Science*, **102**, 454 (1945).